TRANSACTIONS

OF THE

ROYAL SOCIETY OF SOUTH AFRICA.

VOLUME XXX.

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TRANSACTIONS

OF THE

ROYAL SOCIETY OF SOUTH AFRICA.

VOL. XXX.

POTTERY FROM BECHUANALAND AND RHODESIA.

By J. F. Schofield, A.R.I.B.A.

(With three Text-figures.)

(Read March 20, 1940.)

Section I. THE POTTERY FROM TOUPYE.

Introduction.

The bulk of the pottery from Toupye (Topsi) Koppie, in Bechuanaland, was collected during 1938 by Mr. V. Ellenburger, the District Commissioner at Serowe.

This koppie forms a prominent landmark at a distance of about 1½ miles to the north-west of Topsi railway siding. It has obviously been a centre of some importance, as the soil for an unknown depth is made up of occupational material, of which pottery forms a considerable portion.

The site was also visited by Professor C. van Riet Lowe, who noted several resemblances between its archaeological material and that of the Limpopo Valley Sites and more particularly to that from Bambandyanalo. Not only did he find similarities in the pottery, but highly stylised human figurines and a large type of green bead which had been made by melting down small glass beads were common to both places.

It was during this visit that the discovery was made of a human skull which had been buried in a large beaker bowl. We are informed that this skull has many anatomical features which indicate that it is related to the skeletons from Mapungubwe.

From the material collected, it is evident that several different pottery industries are represented, which we will endeavour to classify. Unfortunately we are unable to do more than indicate the probable affinities of these wares, for although the Mangwato have, in accordance with their

traditional history, occupied the place up to fairly recent times, it would in our opinion be unwise to definitely attribute the pottery to any particular tribe, in view of the total absence of stratigraphy, and thus of any indication of the sequence in which it was deposited.

Description of the Pottery.

All the pottery consists of hand-made wares, apparently made from natural clay, and generally very badly burnt. Indeed it is not too much to say that any well-burnt pieces which occur are due to secondary burning which may occur accidentally on any midden.

The pottery had been treated in a variety of ways, which were used either singly or more frequently in combination; these we may enumerate as:—

1. *Surface Finish.*

(*a*) Left smooth from the hand.

(*b*) A matt finish.

(*c*) Burnished.

2. *Colour Decoration.*

In addition to the above, many of the pieces were coloured, with a red, brown, purple, or black surface, and sometimes with a combination of two or more colours on the same vessel.

3. *Graphic Decoration.*

(*a*) Incised lines, made on the wet clay, and occasionally on the dried pot before burning (**2,** 15).

(*b*) One example of engraved lines made after burning (**2,** 16).

(*c*) Comb marks.

4. *Moulded Decoration.*

The treatment of the lips of many of the pots and their neck-bands may be so described.

Classification of the Pottery.

From a purely typological standpoint, the sherds from this site may be classified as belonging to three categories, which we will describe separately.

Category (*a*).

The pottery which we include under this head is, generally speaking, a common domestic ware, frequently finished with a shade of red, brown, or purple matt surface, which, however, in many instances, may have been at one time burnished.

From the sherds at our disposal we can distinguish the following vessels:—

The Shallow Bowl or Platter (**1,** 3) and (**1,** 9).

The first of these has the internally bevelled rim, which is so characteristic of the bowls from the Limpopo Valley Sites. The second is a very rough piece of work.

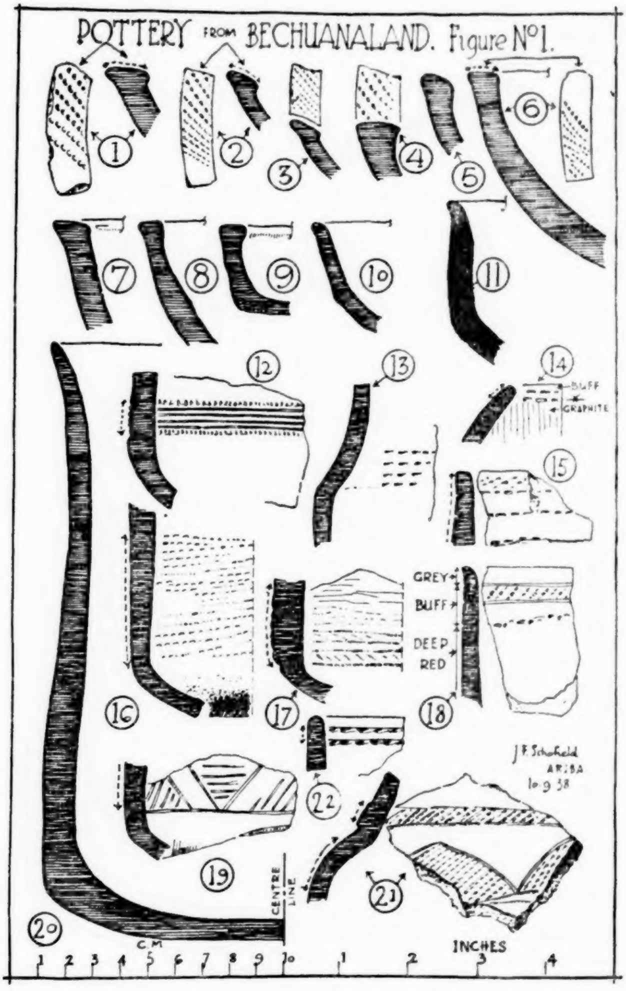

Fig. 1.

The Deep Bowl (**1,** 1), (**1,** 4), (**1,** 5), (**1,** 6), (**1,** 7), and (**1,** 8).

The rims of these bowls are either flattened or have the internal bevel, and in addition several have a decoration consisting of diagonal comb marks.

In addition to these, there are two bowls, (**1,** 2) and (**1,** 10), which are intermediate between the shallow and the deep bowl.

The Beakers.

The commonest type of beaker is rather tall in proportion to its width and practically cylindrical with a very flat base (**1,** 20) and (**3,** 7), which, however, came from Lose. Only one example of a small beaker was found (**1,** 11), and this has a distinctly angular contour.

The Pots.

As will be seen from fig. 2, practically every stage is represented between the spherical pot and the shouldered pot with a concave neck.

It is to be noted that the decoration, when present, usually consists of diagonal comb marks on a convex neck-band, which is very similar to one from Mapungubwe ((1) pl. xxxi, 9).

The pots vary greatly in size, from (**2,** 3), which measured 11 inches over the rim, to (**2,** 17), which was not more than 3 inches in diameter.

The pot with the vertical neck (**2,** 21) may belong to this category, although it is very similar to pots from Parma ((1) pl. xxix, 9 and 10).

Discussion.

The importance of the pottery of Category (*a*) lies in the fact that it presents us with a combination of traits, which have never before been recorded as occurring in conjunction.

For example, the bowls reproduce very faithfully the rim section which we have noted at Mapungubwe (1) and Bambandyanalo, but, whereas these were left plain or occasionally decorated with engraved lines, at Toupye all the decoration was made with the comb. It is true that the use of the comb in rim decoration has been recorded from Gokomere, but on that site such use was very rare, and it was never applied to the bevelled rim, of which only one example was found.

In much the same way the shouldered pots, with comb decorated neck-bands, (**2,** 13), (**2,** 17), (**2,** 18) and (**2,** 19), all conform very closely to the contours of similar pots of Categories M_1 and M_2 from the Limpopo Sites, where comb decoration is so unusual that all examples of it are probably due to direct importation.

The beakers by themselves would indicate that a close connection existed between Toupye and the Limpopo Sites, but even so the two sets

of beakers are by no means identical, for while at Bambandyanalo nearly every one of the beakers and beaker bowls was decorated, and many of

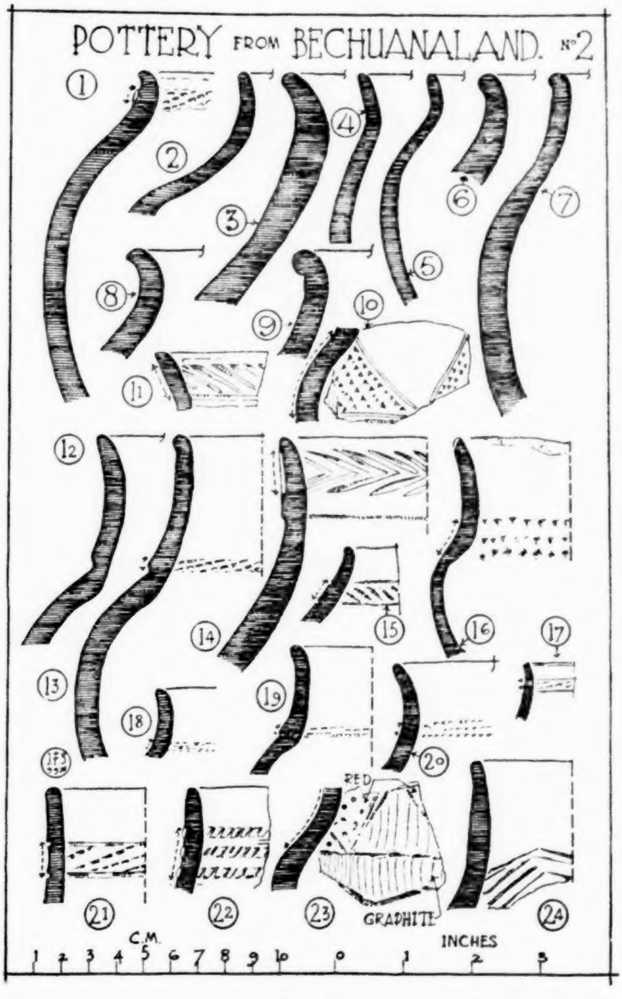

Fig. 2.

the beakers had vertically pierced lugs, at Toupye lugs are unknown, and it is probable that all the decorated beakers were imported.

Category (b).

The outstanding feature of the wares of this category is the use of polychromic decoration combined with comb impressions. The colours used include buff, graphite, grey, brindled and deep red.

The types represented include a spherical pot (**1**, 14) and beakers (**1**, 15) and (**1**, 18).

Discussion.

It may be urged that this category represents nothing more than the finer wares of Category (*a*). This indeed may well be the case, but, on the other hand, the polychromic surface finish probably connects it with the modern Pedi wares, which have little in common with that category.

Category (c).

This category is represented in this collection by a large number of fragmentary sherds of a very coarse pottery, of which (**2**, 23) (which is a fragment of a large shouldered pot) is an example. Its distinguishing features are the use of coloured surface finishes, usually graphite and dull red, the colour areas of which were divided by roughly incised lines, and the picking out of these areas with stippling.

This ware appears to be comparatively modern, and to be connected with the polychromic pottery of Southern Rhodesia which we have included under Class R_3 (2).

It is probable that (**3**, 3) should be included in this category, although it is much finer than the majority of the other sherds.

Miscellaneous Pottery.

In addition to the three categories detailed above, there are a number of pieces which can be attributed, with some certainty, to known pottery traditions, and which should therefore be considered as imported wares.

Gokomere.

The beaker (**1**, 16) is very similar to pottery from Gokomere, and also Mumbwa (3 and 4). The pot rim (**2**, 11) resembles pieces from the former site, and also one which was found at Parma, on which site it was probably an import ((1) pl. xxxii, 7).

The Limpopo Sites.

The beakers (**1**, 12), (**1**, 17), and (**1**, 19) are all practically identical to pieces from these sites. In the first of these the resemblance is to ((1) pl. xxvi, 7) and is particularly striking, the more so since our piece had, in the decorated band, a single projecting lug, for such lugs in this position appear to be of the distinguishing features of Category M_2 pottery from these sites.

The fragment (**1,** 17) is the only piece from Toupye which had been decorated with engraved lines, the use of which is a very characteristic feature of the M_2 wares, while (**1,** 19) is very similar in its treatment to ((1) pl. xxvi, 6).

The fragment of a shouldered pot, (**2,** 24), bears a striking similarity to pieces, also of shouldered pots, from Parma ((1) pl. xxix, 13 and 15).

Ambo Pottery.

Several pieces of Ambo pottery were found at Toupye, unfortunately they were all too small for illustration.

Ila Pottery.

One piece, (**1,** 21), has a certain resemblance to Ila pottery from Northern Rhodesia, now in the South African Museum, Cape Town.

In addition to these pieces, there are a number of sherds which probably belong to undescribed pottery traditions rather than to any of our categories. These may be described as follows:—

The Carinated Sherd (**1,** 13).

Carinated pottery has been taken on a number of sites, such as Mapungubwe ((1) pl. xxxii, 1), Echo (2), and Gokomere (3), but nothing like our example has been recorded before. It seems probable that the ridge of the carination represents an ancient technical process, such as that of making the body and the neck of a pot in separate pieces and subsequently joining them together, the line of the union of the pieces being both marked and masked by the carination. We suggest also that, after this process had been abandoned, the carinated profile survived as a decorative feature. This is certainly borne out by the fact that many of the carinated vessels, particularly those from Gokomere, had been very highly finished, and might well have been intended for the use of persons of importance, whose tastes are proverbially conservative.

The small Shouldered Pots (**2,** 10) and (**2,** 16).

Both of these pieces may belong to our Category (*a*), but they were decorated with impressions which had been picked into the burnt pot, and as this technique has not been recorded before, we accord them a place of their own.

The small Pot with a Vertical Neck (**2,** 22).

This pot has a very similar contour to the vertically necked pots from Parma, mentioned above. But the decoration in this form is new to us, and we therefore mention it separately.

A General Discussion and Conclusions.

We believe that no one who has read the foregoing description of the pottery from Toupye will dispute that it is a very mixed grill, or that its

chief characteristic is its extreme variety. We suggest that this is due to the fact that Toupye lies on one of the most ancient of the great routes of the Sub-Continent. In historical times Mzilikazi and Sebetwane must have used this road, and before their time many a prehistoric conqueror had been by the same way. While the numerous examples of imported wares indicates, clearly enough, the widespread relations which existed with other tribes.

The character of the pottery recovered inclines us to the belief that Categories (*a*) and (*b*) are each due to a separate branch of the Sotho Sub-group of the Southern Bantu, and that the wares of Category (*c*) were made by a people from Southern Rhodesia, who had been tinged with a tincture of the Roswi-Venda culture.

SECTION II. THE POTTERY FROM OTHER SITES.

The remaining pottery has been collected from several sites in Bechuanaland and Southern Rhodesia. Except where stated to the contrary, all of it was picked up from the surface of the ground. It is recorded here for comparative purposes and also to indicate the distribution areas of the various wares.

(1) *Serowe.*

This piece, (**2,** 14), is a fragment of the rim of a large shouldered pot. Its chief point of interest lies in the fact that its well-defined rim band has something in common with some of the wares from the Tunnel Site at Gokomere (see **3,** 14). With this, another sherd was found which belonged to a shouldered pot with a slightly flared neck which was decorated with a band of comb marks, and exactly resembled the pot illustrated on (1) pl. xxvii, 12, and there can be little doubt but that both these latter belonged to the same pottery industry.

(2) *Formona Farm, Bembesi River, Inyati, Southern Rhodesia.*

The fragments of two rough bowls from this site are illustrated, (**3,** 1) and (**3,** 2). The only point of interest is to find the projecting rim-band of (**3,** 2) so far north.

(3) *Matetsi, Southern Rhodesia.*

Of the two pieces from this site (**3,** 3) resembles the last described, but (**3,** 4) is much finer and is probably related to the Category (*b*) wares from Toupye.

(4) *Pottery from an unnamed Koppie, 20 miles north-east from Molepolole.*

This pottery has much in common with that from Toupye. A number of pieces are decorated with comb marks, but all of them, with the exception of (**3,** 6), are too small for illustration. In addition to these there are

several small fragments which were decorated with rough lattice bands which had been incised with a sharp implement.

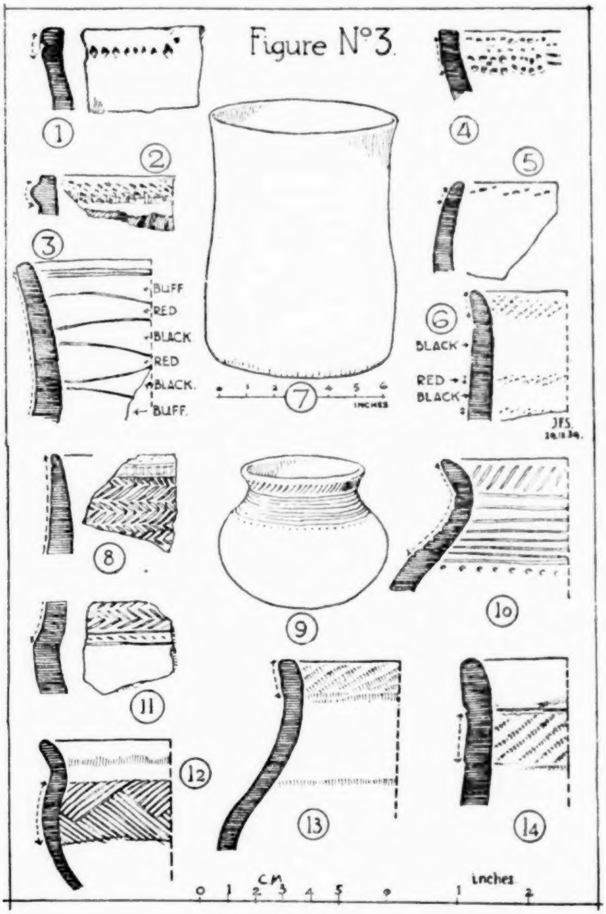

FIG. 3.

The most interesting pieces are two fragments, **(3,** 8) and **(3, 11)**, of what were probably similar pots, for both are decorated with wide herring-bone bands. The vertical rim of the one, and the carinated profile are reminiscent of wares which we have termed Category M_3a at Mapungubwe **((1)** (pl. xxxii, 1), all of which are, however, in polychrome.

This herring-bone ware probably belongs to a distinct pottery tradition, but this is only known to us at present through sporadic fragments which have been found on several sites, such as Mapungubwe and Toupye.

(5) *Gokomere. Pottery from W. × N. Site.*

This site is an open one, but it is near a shelter. Two fragments were found of the little pot (**3,** 9 and 10) at a depth of 24 inches in a dark-coloured soil, where it was associated with Wilton implements and three beads.

The pot is very much worn and is incrusted with a calcareous deposit and is probably of a great age. Presumably it is earlier than any of the pottery taken on either the Tunnel or the Cave Sites, for while those wares were found in deposits which contained no Stone Age material whatsoever, this pot was found at a lower level than Wilton implements.

The decorative features of this pot, *i.e.* the everted rim-band with diagonal incisions, the concave neck with horizontal lines, and the line of point impressions around the shoulder, are all characteristic of Class R_1 wares. It is, however, distinctly unusual to find a pot of this class which shows no use of the comb in its decoration.

The three beads which Father Gardner found in the same stratum as the pot are of two types, of which one is the well-known blue hexagonal, called by the Venda *mavhadwa.* It is of no great age, for we judge it to be no earlier than the third decade of last century. The other two are cylinders of light greyish blue cane glass, $2{\cdot}5 \times 4$ mm. They probably belong to our Second Series, which includes the rarer types of the beads of the Venda Canon, and which may be provisionally dated as being later than the middle of the seventeenth century (5).

It is hardly necessary for us to point out that the presence of beads in an unsealed deposit, such as the one under review. cannot be used as evidence for its date. The Class R_1 pottery, on the other hand, has been found so frequently in positions which are suggestive of an early date, that we regard it as being much more reliable, for we consider it as being the commonest of the early types of pottery introduced by the Bantu Occupation.

(6) *Pottery from the Irene Mine, near the Bulawayo-Plumtree Road.*

This fragment of a shallow bowl, (**3,** 12), is a very good example of the wares which we have classified as R_2, of which the Category M_1 pottery from Mapungubwe is the outstanding type.

(7) *Pottery from Que-Que.*

The sherds (**3,** 13) and (**3,** 14) came from this place. The first of them is similar in some respects to some of the pottery found in the upper third of the deposit in the Tunnel Site at Gokomere, which has been classified on

that site as Category (*b*). It was associated with beads which are probably not earlier than the last quarter of the eighteenth century, but which may be half a century later.

The sherd (**3,** 14) has points of similarity to the pottery recovered from the lower two-thirds of the same deposit, for the bold vertical rim-band and the surface finish are both characteristic of the wares we have there termed Category (*a*), which we regard as being a phase of our Class R_1 pottery (3).

(8) *Beaker from Lose,* 16 *miles north of Mahalapye Station.*

This beaker, which is illustrated (**2,** 20 and **3,** 7), is very similar to the beakers from Toupye; as it is more complete, we can gain from it a good idea of what they must have looked like. It can be classified with the Category (*a*) wares from Toupye.

DESCRIPTION OF TEXT-FIGURES.

Text-figure No. 1.

1. A fragment of the rim of a deep bowl, 11½ inches over the rim. In a pink clay with a matt surface. The rim was flattened and had rounded projections on both sides. It was decorated with comb impressions. Category (*a*), from Toupye.

2. A fragment of a bowl, about 7 inches over the rim. In a fine grey clay with a reddish brown burnished surface internally and a brindled matt finish externally. The rim was bevelled to the interior with rounded projections on both sides and decorated with sharply made patches of comb marks. Category (*a*), from Toupye.

3. A fragment of a shallow bowl, 7 inches over the rim. In a fine brown clay, finished internally to a brindled matt, and smoothed externally. The rim was bevelled internally with a slightly rounded projection on each side, and decorated with lines of fine comb marks. Category (*a*), from Toupye.

4. A fragment of a deep bowl. In a gritty grey clay, with a matt surface. The rim was widened on the inside and decorated with comb marks. Category (*a*), from Toupye.

5. A fragment of a large deep bowl. In a grey clay, with a black burnish internally and a matt surface externally. The rim was widened and bevelled on the inside, and had a rounded projection on the outside. Category (*a*), from Toupye.

6. A fragment of a deep bowl, about 12 inches over the rim. In a grey clay, with a greyish brown matt surface. The rim was flattened and rounded with a slight internal bevel and an external projection. It was decorated with patches of irregular comb marks. Category (*a*), from Toupye.

7. A fragment of a deep bowl, about 12½ inches over the rim. In a gritty grey clay with a purplish grey matt surface. The rim was flattened with a slight internal bevel, and had a burred projection on the outside. Category (*a*), from Toupye.

8. A fragment of a deep bowl, about 11 inches over the rim. In a fine grey clay with a matt surface. The rim was flattened and rounded with a slight burred projection on both sides. Category (*a*), from Toupye.

9. A fragment of a shallow bowl or platter, 4 inches over the rim and 1¼ inches in height. In a gritty grey clay with a light grey matt surface. The rim was thickened on the inside, flattened and rounded on both edges. Category (*a*), from Toupye.

10. A bowl, 4 inches over the rim and $1\frac{3}{4}$ inches in height. In a gritty reddish clay with a matt surface internally and a reddish brown burnish externally. The rim was rounded and slightly everted. Category (*a*), from Toupye.

11. A small beaker, $3\frac{1}{2}$ inches over the rim and about $2\frac{1}{2}$ inches in height. In a grey clay, smoothed internally with a matt surface externally. The rim was rounded and slightly flared. Category (*a*), from Toupye.

12. A fragment of a beaker, about 5 inches in diameter. In a light grey clay, smoothed internally with a matt finish externally. Just above the base it had a slightly projecting band formed with four sharply incised lines, between two lines of small incisions, all of which were made on the wet clay. Miscellaneous pottery from Toupye.

13. A fragment of a carinated pot, about 10 inches in diameter. In a reddish clay, rough internally and a matt surface with specular mica externally. Just above the ridge there was a patch formed with four lines of deep, short, horizontal impressions which had been made on the wet clay. Miscellaneous pottery from Toupye.

14. A fragment of the rim of a spherical pot. In a gritty grey clay with a smooth brown surface internally, externally it had a buff matt finish above the lines of comb marks and a burnished graphite finish below them. The rim was rounded. Category (*b*), from Toupye.

15. A fragment of a beaker, 8 inches over the rim. In a grey clay with a brindled burnished surface. The rim was rounded, and below it there was a band of diagonal comb marks, below this there were three horizontal lines of comb marks. Category (*b*), from Toupye.

16. A fragment of a beaker, about 7 inches in diameter. In a gritty grey clay with worn surfaces. The outside was probably finished matt. Just above the base it had a wide band of carelessly made comb marks. Miscellaneous pottery from Toupye.

17. A fragment of a beaker, about 5 inches in diameter. In a gritty brown clay, smoothed internally and matt externally. Just above the base there was a band of roughly engraved horizontal lines with two lines of diagonal hatching between them. Miscellaneous pottery from Toupye.

18. A fragment of a beaker, 7 inches over the rim. In a grey clay with a brindled burnish internally and a matt finish externally. The rim was rounded and slightly everted. Below the rim there was a band of diagonal comb marks between two lightly incised lines. Below the band there was a sloping line of comb marks. Below this line the surface was coloured deep red. The rim above the band was coloured buff. Category (*b*), from Toupye.

19. A fragment of a beaker, about 7 inches in diameter. In a light grey clay, smooth internally and matt externally. Just above the base there was a band, formed with triangles, separated by plain bands, and alternately filled in with horizontal and diagonal hatching, all of which had been cut on the wet clay. Miscellaneous pottery from Toupye.

20. A reconstructed beaker, 7 inches over the rim by $8\frac{1}{4}$ inches in height. In a well-burnt reddish clay, smoothed internally with a light reddish brown matt surface externally. The rim was rounded and slightly flared. Category (*a*), from Lose, 16 miles north of Mahalapye Station.

21. A fragment of a pot, about 8 inches in diameter. In a grey clay with a rough grey internal surface and a black burnish externally. On the shoulder there was a slightly projecting band of diagonal comb marks, below which there was a line of triangles outlined on the wet clay and filled in with diagonal comb marks. Miscellaneous pottery from Toupye. Similar to Ila, Kawendi, and Lungu wares from Northern Rhodesia.

22. A fragment of a beaker rim, about 9 inches across. In a gritty grey clay, rough internally and a pink matt externally. The rim was rounded and below it there were two lines of steeply made incisions. Miscellaneous pottery from Toupye.

TEXT-FIGURE No. 2.

1. A spherical pot with a shouldered neck, 4½ inches over the rim and about 7¼ inches in diameter. In a gritty reddish clay, smooth internally with a dull red brindled smooth surface externally. The rim was rounded and everted. The neck was decorated with a slightly convex band of comb marks. Category (*a*), from Toupye.

2. A fragment of a shouldered pot, 7 inches over the rim. In a gritty greyish clay, finished with a brown smooth surface. The rim was rounded and the neck slightly flared. Category (*a*), from Toupye.

3. A fragment of a shouldered pot, 11 inches over the rim. In a gritty reddish clay with a brown matt surface. The rim was rounded and the neck was flared. Category (*a*), from Toupye.

4. A fragment of a pot with a short flared neck, 10 inches over the rim. In a gritty black clay, with a greyish brown matt surface. The rim was rounded. Category (*a*), from Toupye.

5. A fragment of a pot with a flared neck, 4½ inches over the rim. In a gritty grey clay with a reddish brown surface, smooth internally and matt externally. The rim was rounded. Category (*a*), from Toupye.

6. A fragment of the rim of a shouldered pot, 12 inches over the rim. In a grey clay with a reddish brown surface, smooth internally and burnished externally. The rim was rounded, slightly undercut and everted. Category (*a*), from Toupye.

7. A shouldered pot 6½ inches over the rim. In a gritty black clay with a deep red surface, smooth internally and matt externally. The rim was rounded and finished externally with a slight burr, the neck was nearly vertical. Category (*a*), from Toupye.

8. A fragment of the rim of a shouldered pot, 7 inches over the rim. Similar to (6), but the rim was more decidedly undercut and everted. Category (*a*), from Toupye.

9. A fragment of the rim of a shouldered pot, 9 inches over the rim. Similar to (6), but the neck was short and vertical, and the rim was made with a well-marked roll. Category (*a*), from Toupye.

10. A fragment of a pot about 6 inches in diameter. In a blackish clay with a red smooth surface internally, and a dull red burnish externally. The lines of a band of triangles had been cut on the wet clay, and stippled with a triangular point after the pot had been burnt. Miscellaneous wares from Toupye.

11. A fragment of a pot with a short flared neck, about 5 inches over the rim. In a grey clay with a matt surface, light brown externally. The rim was rounded on the inside, and the neck was decorated with a band of bold diagonal lines between two horizontal lines. Miscellaneous, similar to pots from Parma and Gokomere, from Toupye.

12. A fragment of a pot with a short concave neck, 6 inches over the rim. In a gritty black clay with a brindled buff surface, smoothed internally and matt externally. The rim was rounded and slightly everted. There was a slightly projecting neck band. Category (*a*), from Toupye.

13. A pot with a short concave neck, 5½ inches over the rim. In a gritty grey clay with a reddish brown surface, smoothed internally and matt externally. The rim was rounded and slightly everted. The neck band had a slight projection and was decorated with diagonal comb marks. Category (*a*), from Toupye.

14. A fragment of a shouldered pot, about 9 inches over the rim. In a gritty light grey clay with a brick red matt surface. The rim was rounded. The slightly projecting rim-band was vertical and decorated with a boldly cut line of herring-bone hatching. From Serowe.

15. A fragment of the rim of a spherical pot with a shouldered neck. In a grey clay

with a smooth buff surface internally, and a matt sepia finish externally. The rim was rounded, and the neck band of rough diagonal hatching between two horizontal lines had been cut on the dried pot before burning. Category (*a*), from Toupye.

16. A fragment of a shouldered pot or bowl with a concave neck, about 6 inches over the rim. In a dark brown clay with a matt surface, brindled internally and reddish brown externally. The rim has been worn off. The neck was decorated with a band of rough impressions which had been made on the burnt pot. Miscellaneous, from Toupye.

17. A fragment of a shouldered pot, 3 inches over the rim. In a black clay, with a grey matt surface internally and a burnished sepia finish externally. The rim was rounded on the inside, and the neck slightly flared. The neck band was a band of diagonal comb marks. Category (*a*), from Toupye.

18. A fragment of a pot with a short concave neck, 4 inches over the rim. In a dark grey clay with a rusty matt surface. The rim was rounded and everted, and the neck had a band of three lines of fine comb marks. Category (*a*), from Toupye.

19. A fragment of a pot with a short concave neck, 7 inches over the rim. In a gritty black clay with a matt surface, smooth internally. The rim was rounded and slightly everted. The convex neck band was decorated with rough comb marks. Category (*a*), from Toupye.

20. A fragment of a pot with a short concave neck, 4½ inches over the rim. In a light brown clay, the external surface and the interior of the rim were finished with a sepia burnish, and the remainder was smoothed. The rim was rounded and the neck had three lines of fine comb marks. Category (*a*), from Toupye.

21. Probably a rim fragment of a beaker, about 6 inches across. In a grey clay with a brick red matt surface. The rim was rounded and flattened, and the neck had a band of diagonal comb marks between two deeply incised lines. Miscellaneous, from Toupye.

22. A neck fragment of a pot or a beaker, about 6 inches over the rim. In a black clay with a dark buff matt finish. The rim was rounded, and the neck had three lines of sloping impressions which had been made with a chisel-shaped tool. Miscellaneous, from Toupye.

23. A fragment of a pot about 9 inches in diameter. In a black clay with a rough grey surface internally, externally it was decorated with a band of dull red and stippled triangles, alternating with graphite burnished triangles. Below this band the pot was burnished with graphite. Category (*c*), from Toupye.

24. A fragment of the neck of a shouldered pot, about 8 inches over the rim. In a gritty grey clay, with a light buff matt surface. The rim was rounded, and the vertical neck was decorated with roughly incised hatched triangles. Miscellaneous, similar to pots from Parma. From Toupye.

Text-figure No. 3.

1. Probably a fragment of the rim of a bowl, 9 inches over the rim. In a grey clay with a smooth surface. The rim was flattened and slightly introverted, externally there was an irregular line of impressions below the rim. A surface find from Formona Farm, Bembesi River, Inyati, Southern Rhodesia.

2. A rim fragment of a vessel 12 inches over the rim. In a grey clay with a brick red smooth surface. The rim was flattened and had a convex rim band with rough diagonal comb marks or incisions, and as last.

3. A vessel of uncertain type, 8 inches over the rim. In a grey clay with a buff matt internal surface, externally the surface was burnished and divided horizontally by roughly incised lines into undulating bands, coloured successively buff, red, black, red, black and

buff. The rim was slightly flattened and the neck was concave. Category (*c*), from Toupye.

4. A fragment of the rim of a 10-inch bowl. In a grey ware with a smooth pink surface. The rim was flattened and below it there was a rough band of comb marks. From Matetsi, Southern Rhodesia. A surface find.

5. A bowl with a constricted opening, 8 inches over the rim. In a grey clay with a brick red matt surface. The rim was flattened and directly below it there was a line of impressions which had been made with a three-pointed comb. As last.

6. A beaker bowl, 8 inches over the rim. In a grey clay with a black matt surface. The rim was rounded and slightly everted. Below the rim there was a band of diagonal comb marks, below that there were two others, of which the uppermost was coloured red. Surface find from a koppie 20 miles north-east of Molepolole.

7. See text-figure No. 1, 20.

8. A fragment of the rim of a vessel, about 6 inches over the rim. In a grey clay, finished smooth red internally and a pink buff matt externally. The rim was flattened, and below it there was a line of lattice, and below that again there was a wide band of herring-bone hatching. As No. 6 above.

9 and 10. A fragment of the rim of a small pot with a concave neck, 4½ inches over the rim. In a dark grey gritty clay, with a worn brindled surface, probably matt. The rim was rounded and everted with diagonal lines incised. The neck had eight horizontal lines forming a band, and below this there was a line of round impressions. From 24 inches below the surface at W. × N. Site Gokomere.

11. Probably a fragment of a carinated bowl, 10 inches in diameter. In a greyish clay, smooth internally and a buff matt externally. Directly above the carination there was a band formed of short diagonal lines between two horizontal lines, above this there was a wide band of herring-bone hatching. As No. 6 above.

12. A shallow bowl, 12 inches over the rim. In a fine grey clay with a good black burnish. The rim was rounded and everted and the body was decorated with a wide counterhatched band cut in a fine style on the wet clay. Identical with Category M_1 wares from the Limpopo Sites. Class R_2, from the Irene Mine, near Bulawayo-Plumtree road.

13. A fragment of the rim and concave neck of a shouldered pot, 6 inches over the rim. In a grey clay with a reddish brown matt surface. The rim was flattened, the rim band had a slight projection, and had shallow diagonal comb marks, below which there was a double line of similar impressions. There was also a line of similar comb marks on the shoulder. A surface find from Que-Que. Class R_1.

14. A fragment of a bowl about 8 inches over the rim. In a deep brown clay which may have had a black burnished surface. The rim was rounded and the rim band plain with a slight projection. Below this there was a band of diagonal impressions which may have been made with a string of beads. A surface find from Que-Que. Class R_1.

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A STUDY OF THE OLD TRADE BEADS OF NYASALAND.

By J. F. Schofield, A.R.I.B.A.

(With one Text-figure.)

(Read March 20, 1940.)

Introduction.

The importance of the study of the beads of an archaeological site, as a means by which its contents might be dated, was brought into prominence for the first time in South Africa by Caton-Thompson's work at Zimbabwe (1). Since the publication of Zimbabwe Culture, much more material has come to light, particularly at Mapungubwe in the Northern Transvaal, and the correlation of the archaeological material with the beads still in the possession of native peoples, has been carried several steps further (2 and 3).

This paper has been divided into three sections, under each of which a separate collection of beads has been considered, as follows:—

Section I.—This section deals with beads which were collected by Mrs. Margaret Metcalfe of Zomba, whose notes on her discoveries are given in her own words. Mrs. Metcalfe has very kindly made her collection available to South African students by presenting representative examples to the Museum of the Bureau of Archaeology at the Witwatersrand University.

Section II.—This section deals with a collection of beads which was made by Mr. R. C. Wood in Northern Nyasaland. Mr. Wood has also presented all these beads to the Museum of the Bureau of Archaeology.

Section III.—This section deals with a collection of fifteen beads which were sieved from the dust of a cave floor in the Hora Mountain, Nyasaland, by Mrs. Joan Boardman and Mr. C. E. Boardman.

Section I.

String No. I/1.

The beads on this string belonged to Chief Mpimbi, of the Zomba District, who considered them to be very old.

Generally they are looked upon as heirlooms, and in a number of

examples they show signs of considerable wear. They are called *Ntiza* in Ngoni, and *Chitalaka* in Yoa and Nyanja.

These are large spherical beads, consisting of a core of opaque white wound glass, covered with a thin coating of deep red transparent wound glass. 21 × 24 mm.

These beads appear to be similar, in everything but their size, to the beads on String No. I/2, which is described below.

String No. I/2.

These beads were found in a large cave at Malape, near Chikala. This cave had been an ancient tribal hiding place of the local Nyanja people. It consists of a series of rocky caverns, entered through a small concealed cleft. It had been undisturbed for many years, for the bat guano lay a foot deep in places. The beads were found on a ledge of rock covered deep in dust. In Yoa and Nyanja they are called *Chitalaka*.

These are barrel-shaped beads; the core is of opaque white wound glass, covered with deep red transparent wound glass. 12 × 11 mm.

This is an old type of trade bead, and with many variations of coating and core are found over a large area of the Sub-Continent. In the Luangwa, Northern Rhodesia, they are called *Chitalaka*. Susi and Chuma told Horace Waller that these beads were valuable in every part of Africa. That they were called *Sami sami* by the Swahele, *Chitakaraka* by the Waiyou, and *Mangazi* (Zulu iGazi, blood) by the Nyassa (4). Livingstone also mentions having ordered 6 frasila of *Talaka* beads to be sent to him from the Coast. From this we can conclude that during the sixties of last century they were being imported into Nyasaland as trade beads. According to native tradition, they were introduced into Northern Rhodesia by Arab slave traders, and "a girdle sufficient to encircle a slave offered for sale was the price of a male or a female slave" (5).

String No. I/3.

These beads were obtained from natives who stated that the red ones were "old beads," but not "very old." The black beads are scarcer, and show signs of having been in use for a long time, for, unlike the red beads, they are often very worn.

(*a*) These beads are similar to the beads on String No. I/2, but decorated with white eyes.

(*b*) Spherical beads of black wound glass, decorated with white eyes. 10 × 10 mm.

(*a*) These beads were great favourites in Bechuanaland during the latter part of the nineteenth century. The blue on white variety is called *Traina*, because they were introduced at the same time as the railway. They have been recorded from Northern Rhodesia, but they do not appear to have been imported into the Eastern Transvaal or Natal, where they are found very rarely.

Professor C. van Riet Lowe has informed the writer that the beads are probably German or Venetian imitations of native-made Nigerian beads, which, failing to find a market on the West Coast, were imported into Bechuanaland where they found a ready sale.

(*b*) It is possible that some of these beads may be of native manufacture from Nigeria. These beads were traded into Northern Rhodesia, and have been found as far south as the Transvaal. Even if they are not the genuine article, they have the appearance of being good imitations of a respectable age.

String No. I/4.

Specimens of these beads have been obtained from all over Southern Nyasaland, including the Lake shore. They are said by the natives to have been brought in by the Arabs for use in the slave trade.

(*a*) The larger beads belong to another variety of the beads which have been described under String No. I/2. Several appear to have been made by folding a strip of glass around a wire, and not by winding, as was the case with the other beads of this type. (See String No. I/5.)

(*b*) Crimson on white, cane glass beads. 3 × 4·5 mm. Livingstone called these beads *Semsem*, they are the commonest type of bead in our Third Series, and appear to have been introduced into South Africa about 1830 (3 and 4).

String No. I/5.

These beads were found by a man while hoeing his garden near Mposa's village.

The beads are oval folded canes of deep red glass on a white base. 8 × 10 to 12 mm.

These beads appear to have been made by the unusual process of welding together two sheets of glass, respectively red and white, to form a single plate, which was then drawn out to give the required thickness. The plate was cut into strips which were folded round a mandrel, and again drawn out, during which process the edges of the strips were welded together to form a cylinder of glass. This was cut into sections of about

8 mm. each, to form individual beads which were finished off by being reheated.

Mrs. Mary Leakey of Kenya has recently informed the writer that she has found an Indian red on a green base cylindrical bead, which had been made by this process, in conditions suggestive of a considerable antiquity. On the other hand, Mrs. Martin of Penhalonga, Southern Rhodesia, found similar beads in the superficial layers at Nyazongo Fort 2, where they were associated with typical beads of our Third Series, which can be dated as being later than about 1830.

String No. I/6.

These beads were found in a small sheltered cave on a precipitous side of Zomba Mountain. The beads were scattered, a few were showing on the surface, and the remainder were buried under as much as eight inches of dust. These beads appear to be the oldest in the collection, as none of them are in use amongst present-day natives. Associated with the beads were the fragments of two or more skeletons, minus the skulls, and some pottery.

(*a*) These beads are long cylinders, respectively 46, 21, and 20 mm. in length, with a diameter of about 8 mm., of opaque Indian red cane glass on a transparent green base.

(*b*) Long cylinders of bluish grey opaque cane glass. 16 to 20 × 7 mm.

(*c*) Long cylinders of transparent cane glass on a whitish base. The outer glass has a good deal of crackle. 25 to 12 × 7·5 to 9 mm.

(*d*) A long cylinder of transparent cane glass with green streaks, on a light grey base. 10 × 9 mm.

(*a*) These long cylinders are the canes from which beads, such as (*a*) of String No. I/7, were cut. The Indian-red-on-green are well known from the Rhodesian ruins, where they are generally accepted as having a late eighteenth century date (6). It is very tempting to regard them as being the *Canutilho* of the Portuguese Records. Lacerda stated that the Cazembe of his day decorated his person with large white beads and *Canutilho* which were greatly valued (7). They were still in use in the time of Monteiro and Gamitto, but they appear to have become obsolete in Nyasaland before 1870, for they were unknown to Chuma, except in Katanga, as they were no longer being imported to the East Coast of Africa (4).

(*b*) These canes appear to be of similar material to the cores described under (*a*).

(*c*) White beads with a crackle surface have been found on several sites in Southern Rhodesia, and in the Northern Transvaal (2), it is probable that they are not earlier than the latter part of the eighteenth century.

(*d*) This type of bead does not appear to have been recorded before, but it is entirely in keeping with the other beads on this String.

String No. I/7.

All the beads on this String were found in an ancient rubbish heap at Old Livingstonia, which is a Nyanja village. A Church of Scotland Mission was started there in the 1870's, but it was soon abandoned. The Nyanja call these beads *Perere*, and the Yoa, *Luperere*. They are said to be old, "long before the old people's grandmothers."

(*a*) These beads are cylinders of Indian red cane glass on a transparent green base. 8 to 12 × 8 mm.

(*b*) Cylinder of opaque white cane glass with a crackle surface. 11 × 8 mm.

(*c*) A fragment of a cylinder of transparent cane glass on an opaque white glass base. 11 mm. in diameter.

(*d*) A cylinder of peacock blue glass on an opaque white cane glass, on a light grey base. 9 × 9 mm.

These beads belong to the same types as those described under String No. I/6.

String No. I/8.

These beads were found during the hoeing of a native's garden, near Monkey Bay, Lake Nyasa.

(*a*) These beads are opaque light blue reheated irregular cane glass beads. 4 × 5 mm.

(*b*) Short barrels of opalescent wound glass. 5 × 9·5 mm. and 12 × 12 mm.

(*c*) A large oblate of black wound glass, encrusted with white eyes. 12 × 15·5 mm.

(*d*) A long barrel of opaque light blue wound glass. 7·5 × 6 mm.

(*a*) In South Africa, light blue beads do not make their appearance until after the first quarter of last century. For example, large quantities of them have been found at Dingaanstad, which was built in 1829 and destroyed in 1838.

(*b*) These beads have a very wide distribution in South Africa, for they are included amongst the ancestral beads of the Venda and the Pedi (8, pp. 351 and 356). They are known as *Matombo* or *Miyala* in the Luangwa Valley, Northern Rhodesia, where they are stated to have been introduced by Arab slave traders, and to have had a similar value to the *Chitalaka* (5).

They may represent the *Pedras Leite* of the Portuguese Records, but

it is more probable that they are nineteenth century imitations of those beads.

(*c*) This bead belongs to the type described under String I/3 (*b*).

(*d*) This bead probably belongs to a blue variety of the type described under String I/9 (*b*).

String No. I/9.

The beads on this String were found under similar circumstances to those already described under String No. I/8. Water-worn beads, very similar to the one marked (*f*), have been picked up at Ras-Mkumbu, on Pemba Island. The natives call them simply *Nkanda ya kale*, or *Chuma*, *i.e.* wealth.

(*a*) This bead is a short barrel of opalescent wound glass. 7 × 12 mm.

(*b*) Long barrels of opaque white wound glass. 9·5 × 7 mm.

(*c*) A long barrel of clouded translucent light blue wound glass. 12 × 7·5 mm.

(*d*) Two long barrels of amber-coloured wound glass. 9·5 × 5·5 mm.

(*e*) An oblate of light blue translucent wound glass. 6 × 9 mm.

(*f*) An oblate of light green opaque wound glass. 7 × 11 mm.

(*a*) This is another example of the type already dealt with under String No. I/8 (*b*).

(*b*) These beads have a very wide distribution, having been found on the shore at Pemba Island, amongst the Herero and the Masai, while the opalescent and black varieties are included by the Venda amongst their ancestral beads and are called *Matshimbaatswina.* It is suggested that this type of bead may have originated as an imitation in glass of the smaller shell beads which were made from the central columns of sea-shells.

(*c*) This bead is probably a blue variety of the last described. Blue beads became popular in the South during the early part of last century.

(*d*) These beads are probably glass imitations of the chalcedony beads which have been manufactured near Negapatam in India, at any time during the last 2000 years. They are still imported into Egypt and the Sudan; they are found along the shore at Pemba Island, and on the Pondoland coast. These last are supposed to be the spoils from Portuguese wrecks.

(*e*) This type of bead was very popular in Natal during the latter part of last century.

(*f*) There is nothing to add to the previous remarks regarding this bead, but it appears to be unknown to the south of the Zambesi.

String No. I/10.

These beads belonged to an old native woman, an Angoni from Ncheu, who said that the opalescent bead, (*a*), had belonged to her grandmother.

(*a*) This bead is a large barrel of opalescent wound glass. 19 × 18 mm.

(*b*) Annular beads of transparent blue wound glass. 4·5 × 13 mm.

(*c*) Annular beads of amber-coloured wound glass. 4·5 × 13 mm.

(*a*) This bead belongs to the same family as the other opalescent wound glass beads already described.

(*b*) These beads are identical with the annular blue glass beads of the Venda and Pedi canons. From the violet tinge in the glass, I believe that they are not older than the middle of last century.

(*c*) These amber-coloured annulars are probably quite recent. They have not been recorded to the south of the Zambesi.

String No. I/11.

These beads came from Karonda at the north-west end of Lake Nyasa, where a few are still to be found amongst the Nkonde. They are said to be very old, and appear to have been handed down from generation to generation as heirlooms. As they are found neither at the southern end of the lake, nor in the central region, it is improbable that they were introduced by the Arab traders. Until recent times the Nkonde had little contact with the outside world, as may be judged by the fact that prior to 1914 they wore no clothes.

(*a*) This bead is a large barrel of opaque light blue wound glass. 27·5 × 22 mm.

(*b*) A large barrel of opalescent wound glass. 26 × 22·5 mm.

It is very tempting to recognise in these two beads, respectively, the *Roncalha azul* and the *Pedras leite* of the Portuguese Records, more particularly since they do not appear to have been introduced by the Arabs. In any case (*b*) belongs to the widespread *Matombo* family. Professor C. van Riet Lowe has informed the writer that both of these types are at present current in Nubia.

String No. I/12.

These beads formed part of a string to which a beetle, called *Chifadala*, was attached. They originally belonged to Kachinamoto, who was a particularly infamous witch doctor.

Small oblates of opaque white glass, one with fine brown lines. 3 × 4 mm. The others, 2 × 3 mm. to 2·5 × 3·5 mm., are without lines.

The bead with the fine brown lines belongs to the large family of striped

beads which is well represented amongst the Venda, Pedi, and Zulu beads. The small white oblate are universal on the sites which yield beads of our Third Series, to which the striped beads also belong (3).

String No. I/13.

The natives value these beads as charms to ensure safe child-birth. It is probable that the old midwives may have seen some resemblance in them to an older type of bead.

> These beads are oblates of light blue pressed glass, with a slightly projecting zone, 3 mm. in width; they measure 8 × 9 mm.

There can be no question but that these beads are quite modern, being imported from Czechoslovakia. They are made in various colours, and are popular in the Rhodesias and in the Central Transvaal, where they are called *macandas*.

Mrs. Metcalfe's suggestion is an interesting one, for blue beads had an ancient vogue in Nyasaland and the neighbouring countries, as the greatly valued *luo* beads bear witness, and Livingstone notes having seen fine blue beads at Mtarika's and at Chimiki Island in the Rovuma, where they were worn in rolls on the neck (4, vol. i, pp. 57 and 68).

String No. I/14.

These beads were dug up, at a depth of about 2 feet, during the excavation for the foundations of a hut. No similar beads appear to have been recorded from this territory.

> The beads are oblates of a greyish green wound glass. 7·5 × 9 mm.

These beads resemble those from Mapungubwe which we have termed, from their shape, "garden rollers." It has been shown conclusively that they were made locally by melting down imported glass beads. It is not improbable that the beads under review were made by a similar process.

String No. I/15.

These beads were found in a large rock shelter on the summit of Chione Mountain in the Chikala Range, which had served in olden times as a tribal refuge for the Nyanja.

With the shell beads were others which resemble those described under String No. 6 (*c*), a broken cowrie shell, a small undecorated pottery bowl, coloured red, a small iron bracelet, and an iron knife blade or spear head. Both of the latter were much rusted, although the place was dry and sheltered.

> These beads were made from the central column of a sea-shell, probably conus. One measures 18 × 15 mm. and the other 23 × 9 mm.

It is evident from their condition that these beads are of a considerable age, but since similar beads have been made for centuries, and as they are still in use, they cannot be used as dating material. They have been found at Pemba Island, and are highly valued amongst the native peoples of Northern and Southern Rhodesia, the Northern Transvaal, and South West Africa. In the whole of this area the shell beads are usually associated with the discs which were made from the shell whorls. See String No. II/36.

Section II.

Mr. Rodney C. Wood, of Livingstonia, Nyasaland, has supplied us with the following details regarding the beads which are discussed under this section:—

"I have obtained," says Mr. Wood, "all the beads from people of the Apoka, Wahenga, and Atumbuka tribes, who inhabit the northernmost district of Nyasaland, between latitudes 9° 20′ south and 11° 10′ south. I can get no definite information regarding any of them, for all that the people who brought them to me could say was, 'They belonged to my *ambuye*.' They were supposed to have been obtained from the Arabs, or to have been traded from *rugaruga*, before the white man came. *Ambuye* means a grandmother or even an ancestress. It seems to be certain that they were imported before the period of the Angoni raids, and tradition has it that they always came from the north with Arabs or *rugaruga*. (I think that the latter were black slave raiders employed by the Arabs.)

"The broad end of a conus shell on String No. II/36 (*Conus mille-punctatus*?) is interesting. One of these is said to have been the price of a slave girl, but I cannot get confirmation of this. They are very rare in this part of Nyasaland."

Strings Nos. II/1 and 2.

Nine large barrel beads of opalescent wound glass, some of which have been much worn down. From 26 × 24 mm. to 8 × 17 mm.

These beads are all robust members of that widespread family which has been dealt with under String No. I/8 (*b*).

String No. II/3.

This is a bead of black wound glass, 18 × 18 mm., and it is probably a black variety of Nos. 1 and 2 above.

Strings Nos. II/4 and 5.

These two shell beads measure respectively 40–28 mm. × 28 mm. and 35–22 × 11–15 mm. See String No. I/15 above.

String No. II/6.

Six much worn and discoloured cylinders of opaque white (?) cane glass, 16 × 9 mm. to 10 × 9 mm.

These beads probably belong to the same general class as those discussed under String No. I/6 (*c*) above, and also String III/(*d*), (*e*), and (*f*). Similar beads have been noted from Northern Rhodesia.

Strings Nos. II/7 and 8.

7. A long cylinder of opaque Indian red cane glass on a transparent emerald green base. 25 × 7 mm.
8. A long cylinder of deep blue translucent cane glass. 31 × 9 mm.

These beads belong to the same general class as String No. I/6. The emerald green base of No. 7 is unusual, the normal base is a light olive green. This bead appears to have been buried in the soil.

Strings Nos. II/9, 10, and 11.

9. A large oblate, 12 × 17 mm., consisting of a base of opaque white cane glass, over which a translucent deep red glass has been wound.

See Strings Nos. I/1 and 2 above.

10. Two irregular short cylinders of deep red cane glass on an opaque white base. 7 × 9 mm. and 9 × 11 mm.

These beads are similar to those on String No. I/5. They were not made by the same process, but are ordinary canes, and are varieties of String No. I/2.

11. Three cylinders of crimson cane glass, on an opaque white base. 4 × 4·5 mm.

See String No. I/4 (*b*) above.

String No. II/12.

Three irregular short cylinders of opaque white cane glass. 5 × 6 mm. to 2 × 5 mm.

Similar beads to these became common in South Africa after 1830.

Strings Nos. II/13 and 14.

13. Three barrels of deep purple translucent wound glass. 10 × 10 mm. to 7 × 10 mm.

These beads are colour varieties of those described under String No. II/9. Similar beads have been recorded from Northern Rhodesia, where they appear to have been introduced in connection with the Slave Trade.

14. (*a*) Two barrels of deep red translucent wound glass. 10 × 10 mm.

These beads are similar to the last described.

14. (*b*) An irregular cylinder of deep red translucent cane glass on a pinkish white opaque base. 10 × 12 mm.

This bead is a variety of the one on String No. II/10.

String No. II/15.

Three long barrels of translucent brown wound glass. 10 × 6 mm.

These beads probably belong to a variety of those described under String No. I/9 (*d*).

String No. II/16.

A pale blue long barrel of semi-translucent wound glass. 12 × 9·5 mm.

This bead is very similar to that described under String No. I/8 (*d*).

String No. II/17.

Three irregular barrels of opalescent wound glass. 8 × 7 mm. to 7 × 7 mm.

These beads are very similar to that described under String No. I/8 (*b*).

Strings Nos. II/18 *and* 19.

Six annular beads of transparent blue wound glass.

These are similar to String No. I/10 (*b*). One bead on String No. II/19 has the greyish tinge which we associate with the earlier type of these beads.

String No. II/20.

Three annular beads of emerald green transparent wound glass.

Similar beads to these have been recorded from Northern Rhodesia, where they are associated with the blue and amber annulars.

String No. II/21.

Two annular beads of transparent amber wound glass.

As last described.

String No. II/22.

Three beads similar to those described under String No. 1/2 (*a*).

String No. II/23.

Three beads similar to those described under String No. I/2 (*b*).

String No. II/24.

Four beads similar to the last, but with white eyes with red centres (fig. 1, 1).

String No. II/25.

Two spherical beads of black wound glass. 10 × 11 mm. Decorated with a zone of specular copper-coloured particles, between two white zones with light green centres, each of these had been wire-drawn towards the end of the head at two points (fig. 1, 3).

These beads are elaborate examples of the encrusted beads which have been recorded from Northern Rhodesia. The wire-drawn detail is unusual, but a fragment showing similar treatment was found at Mapungubwe (2, pl. vi). Beck states that this process was used at Venice.

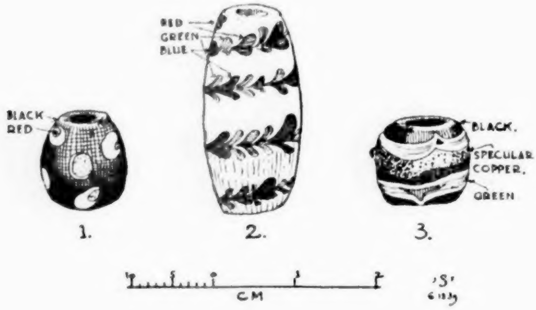

Fig. 1.

String No. II/26.

A long barrel of brownish white opaque wound glass. 25 × 12 mm. Decorated with a floral spiral of four turns, in red, blue, and green (fig. 1, 2).

This bead is of a very unusual character, and nothing like it has been recorded before.

String No. II/27.

Three oblates of semi-translucent whitish glass. 10 × 14 mm. to 11 × 15 mm.

These beads belong to the same general class as those described under String No. I/8 (*b*).

String No. II/28.

A large oblate of opaque sparrow-egg blue wound glass. 12 × 16 mm.

This is another variety of the last described.

Strings Nos. II/29 and 30.

Fifty-five irregular oblates, spheres, and pear-shaped beads, in whitish semi-transparent wound glass. 5 × 8 mm. to 8 × 9 mm.

Three specimens of these beads are twinned, twin beads of a yellow translucent glass, but otherwise very similar to these beads, have been recorded from Northern Rhodesia, where a number are to be seen in the collection of the Rhodes Livingstone Institute, but these are the first which we have seen in this type of bead. The beads do not show a great deal of wear and it is improbable that they are of any great age. Mr. Wood states that they are common amongst the Wahenga and Atumbuka tribes.

String No. II/31.

Three irregular oblates of semi-translucent violet blue wound glass. 7×10 mm.

These beads show a similar amount of wear to the last described, and seem to be another variety of the same general type of bead.

String No. II/32.

Four irregular oblates of semi-translucent bluish grey wound glass. 6×9 mm.

These beads are similar to the last described, regarding age and class.

String No. II/33.

Four irregular oblates of light green translucent wound glass. 6×9 mm.

These beads should be classed with the last three strings.

String No. II/34.

Three irregular oblates of transparent light blue glass. 7×8 mm.

These beads show no sign of wear and are probably quite modern.

String No. II/35.

Two tubular cylinders of opaque sax blue cane glass. 5×7 mm.

These appear to be modern trade beads.

String No. II/36.

A fine example of a shell disc, made from the whorl of a conus shell. 51 mm. in diameter.

These discs are very highly prized over a wide area of Central and South Africa. Amongst the Venda and the Pedi they are called *ndalama* and *talama* respectively. As both of these words are derived from the Arabic *dirhem*, *i.e.* money, we may gauge not only the esteem in which they are held, but also the source of the supply (2, p. 124).

String No. II/37.

Three irregular oblates of transparent amber-coloured glass. 6×10 mm.

These beads are very similar to String No. II/34 above.

Section III.

The fifteen beads which form this collection were seived from the dust of a cave floor in the Hora Mountain, Nyasaland, by Mrs. Joan Boardman and Mr. C. E. Boardman.

(*a*) Part of a large barrel bead of wound glass. The original measurements were probably 34 mm. in length by 10–19 mm. in diameter, with a bore of 5 mm. The whole substance of the bead has been so completely changed that it is impossible to ascertain its original colour.

(*b*) An irregular cylinder of shell. $18{\cdot}5 \times 11$–13 mm.

(*c*) A long cylinder, 17×8 mm., of opaque Indian red cane glass on a transparent green base.

(*d*) A fragment of a long cylinder of slightly greenish transparent cane glass on an opaque white glass base. 7·5 mm. in diameter.

(*e*) A short cylinder of similar glass to the last, but with a pronounced crackle. $7 \times 8{\cdot}5$ mm.

(*f*) A similar bead to the last, but of whiter glass.

(*g*) Three annular beads of transparent blue glass. 5·5–3 mm. $\times$ 12·5–12 mm.

(*h*) Two small oblate beads, probably of reheated translucent cane glass, respectively $1{\cdot}5 \times 3$ mm. and $2 \times 3{\cdot}5$ mm.

(*i*) A similar bead to the last, but of translucent lavender glass. $2 \times 3{\cdot}5$ mm.

(*j*) A cylinder of transparent blue cane glass. $5{\cdot}5 \times 7$ mm.

(*k*) A small oblate bead of translucent white glass. 2×4 mm.

(*l*) An oblate bead of opaque blue wound glass. 6×9 mm.

(*a*) This bead has been so altered that it is impossible to be definite regarding its original colour. Similar beads in opalescent and light blue glass are not uncommon, and are generally considered to be of Venetian manufacture. Their age is uncertain, but judging from their association with such beads as the Blue Annulars, they may be as recent as the middle of last century, but, on the other hand, they may be considerably earlier. See String No. I/8 (*b*).

(*b*) See String No. I/15 above.

(*c*) This long cylinder belongs to the same type as those described under String No. I/6 above.

(*d*), (*e*), and (*f*). These beads have a similar distribution, in Africa, to (*c*), with the exception that the "crackled white" enjoyed at one time a wider vogue than the others, not only in this Continent, but in Asia as well, for it has been found as far away as Malaya. See String No. I/7 above.

(*g*) See String No. I/10 (*b*) above.

(*h*) These two beads seem to be very similar to beads from the Bowl at Mapungubwe. They may therefore belong to our First Series (3), and be of a respectable antiquity.

(*i*) This grey bead is very similar to surface finds at Parma Kopje, and other late sites in the Limpopo Valley, where it would have been included in our Third Series, and dated as being subsequent to 1830.

(*j*) This bead is also similar to examples from Parma Kopje. The glass has the greyish tinge which we associate with the earlier varieties of the Venda *tshinyuke*.

(*k*) Small beads of translucent white glass do not seem to have been imported into South Africa until quite modern times. Although the condition of the bead agrees with our findings, this does not necessarily fix the date of the bead, for other fashions may have prevailed in Nyasaland.

(*l*) This bead is similar to beads from Northern Rhodesia, which are said to have been introduced by the Slave Traders. Modern blue glass beads of a similar colour, String No. I/13, are used as charms to ensure safety in child-birth. All these beads may be imitations of earlier and more valuable beads such as the Luo.

It will be seen from the foregoing that these beads form a very mixed collection. Some of them, such as (*h*), may be several centuries old; others, (*c*), (*d*), (*e*), and (*f*), may go back for a hundred and fifty years or so; while others again, such as (*g*), cannot be more than about eighty years old. In other words, these beads are precisely those which we would expect to find in a cave which had been used as a place of refuge or resort over a long period of years.

A General Discussion.

It is interesting to find that neither the ostrich egg-shell nor the achatina-shell beads are included in these collections. If this should prove, on further investigation, to be a feature of the bead series from Nyasaland, it may serve to connect them with the earliest beads from Zimbabwe and Mapungubwe, amongst which none of these shell beads were found.

With two exceptions, the old Arab beads from Pemba Island are not represented, and this also applies to the coloured clay beads from Negapatam, which were current in the Zambesi Valley during the early years of the Portuguese Conquest.

With the doubtful exception of the bead, String No. III/(*h*), there are no examples of the small bright oblates of our First Series, nor are the small cylinders of cane glass present, which the Pedi call *thaxa*, and which the Venda regard as the rarest of their ancestral beads (3).

Bearing in mind these facts, it is suggested that these collections consist of beads from four groups which, although they are fairly distinct, overlap to a certain extent.

1st Group.—The shell beads from Strings Nos. I/15, II/4, 5, and 36, and III/(*b*).

2nd Group.—The beads on Strings Nos. I/6, 7, 11, 12, and 14, Strings Nos. II/6, 7 and 8, Strings Nos. III/(*a*), (*c*), (*d*), (*e*), and (*f*). These beads were probably introduced by Portuguese traders, *circa* 1750 to 1830. The use of several of these types appears to have been continued by the Arabs until about 1890.

3rd Group.—The beads on Strings Nos. I/1, 2, 3, 4, 8, 9, and 10, Strings Nos. II/1, 2, 3, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 23, 24, 25, 27, 28, 29, 30, 31, 32, and 33, and String No. III/(*g*), (*i*), and (*j*). These beads were probably used by the Arab traders and slavers between 1830 and 1890. Burton, who made a close study of the conditions along the East Coast during the sixties of last century, has informed us that in his time all the beads used in trade were being imported from Venice (8).

4th Group.—The beads on String No. I/13, Strings Nos. II/34, 35, and 37, and String No. III/(*l*), are all quite modern.

Miscellaneous Beads.—The unusual character of the beads on String No. I/5 and Strings Nos. II/25 and 26, renders classification uncertain, although it is probable that they should all be included in the 3rd Group.

Comparative Classification.—From the foregoing it will be seen that the 2nd Group of the above classification coincides in part with the Second Series of the classification which we have proposed for the Prehistoric Beads of the Northern Transvaal, while the 3rd Group has much in common with the Third Series of that classification (3).

The writer has recently had the privilege of examining the beads in the collection of the Bureau of Archaeology at the University of the Witwatersrand, Johannesburg. He was greatly impressed by the manner in which bead types, and indeed whole series of bead types, remain in currency over long stretches of time. Both the provenance of the beads and their currency areas may change, but the types and the type series are much more stable. For example, the striped beads, the crimson on white, the greys, blues and pinks, which are indistin-

guishable from the beads of our Third Series (3), were current at Foustad in Egypt, during the closing years of the twelfth century. In South Africa we find that these types of beads did not become fashionable until about 1830, when vast quantities of them were imported from Italy. Similarly, the ostrich egg-shell bead, which appeared first during the latter stages of the Late Stone Age, is still being made in large quantities in Bechuanaland and the Northern Transvaal, and glass imitations of it are being imported from Central Europe.

Historical Survey.—When history opens, with the Portuguese expeditions of the beginning of the sixteenth century, we find that all the strategic points along the East African coast had long been occupied by Arab settlements, which had also penetrated the Zambesi Valley as far as Tete, while Arab traders were regular visitors to the various fairs which had been established at different places in the country which we now call Southern Rhodesia.

It goes without saying that some knowledge of the north was acquired by the Portuguese at this time, for we know that the route from the Zambesi across Nyasaland to the coast was occasionally used. This knowledge appears to have been forgotten in the decay which befell first the Arab and then the Portuguese settlements of the East Coast.

Indirect trade was certainly maintained, and it is not improbable that coloured traders, such as the *pombeiros*, as they were called on the West Coast, visited the country, but if this was so, we hear nothing of their adventures until one of them, called P. J. Baptista, arrived in Tete in 1811 after a journey which had lasted for nine years, and left us an account of his travels.

Dr. Lacerda in 1798 and Monteiro and Gamitto in 1831 all passed to the west of Nyasaland, but doubtless the conditions of barbaric affluence which they found at the court of Cazembe were maintained by many another local potentate.

Shortly after these visits, the Portuguese power suffered yet another eclipse, this time at the hands of the Angoni, as those hardy Nguni warriors were named who carried the methods of Shaka from Swaziland to the Great Lakes.

These Angoni raids continued into the seventies of last century, and coincided with, and contributed to, the revival of the Arab power which was centred on Zanzibar. The havoc wrought to native life by all this slaving and raiding is pictured for us in Livingstone's *Last Journals*, and it was only finally brought to an end by the European Occupation of the closing decade of last century.

Conclusions.

From the foregoing we believe that we can draw the following conclusions:—

1. That with one doubtful exception, it is probable that the earliest glass beads in these collections belong to our 2nd Group, which may be dated as from *circa* 1750 to 1830.

2. That the bulk of the beads belong to the Slave Raiding Period which coincided with the Angoni and Arab raids between 1830 and 1890, and is represented by our 3rd Group.

3. That a few of the beads belong to the 4th Group, which represents the new direction which was given to trade by the European Occupation.

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NEW SOUTH AFRICAN MITES OF THE GENUS *TENUIPALPUS* DONNADIEU (TETRANYCHIDAE).

By R. F. Lawrence, Ph.D., Natal Museum, Pietermaritzburg.

(With 6 Text-figures.)

(Read August 20, 1941.)

In a recent paper the writer described two new forms of *Tenuipalpus* from Natal. In the present paper further notes on these species have been made, consisting of amplifications of the first descriptions with some observations on the living mites, which were recorded by the writer and Mr. M. Lavoipierre at Durban in July 1940. My sincere thanks are accorded to Dr. H. G. Schweickerdt of the Natal Herbarium, Durban, for his kindness in identifying a number of the plants on which these mites were found, and to Mr. M. Lavoipierre for the excellent mounts made of the type specimens. Mr. Lavoipierre has also assisted me with notes and observations on living specimens.

Genus Tenuipalpus Donn.

Tenuipalpus micheli Lawrence (text-fig. 1, *a–c*).

T. micheli Lawrence, Journ. Ent. Soc. S. Africa, vol. iii, p. 111, text-figs. 4 and 5, 1940.

In the single ♀ specimen on which the type was based, the two long setae at the postero-lateral angles of the abdomen were missing. Further specimens have now been obtained from the type locality and host plant. In these, there is on each side of the opisthosoma a group of five hairs, four of which are flattened and spiculate, that between the third and fifth, however, long and flagelliform (fig. 1, *a*). Its length is about three-fourths the width of the opisthosoma and nearly twice the length of the first flattened hair of the lateral group. The large hair at the antero-lateral angle of the cephalothorax, though rather variable, is longer than as figured in the description of the type (*loc. cit.*, fig. 4). Its length considerably exceeds half the distance between the anterior margin of the cephalothorax and the transverse suture (fig. 1, *b*). The figures now given represent more accurately the structures in question and must therefore supersede those accompanying the original description.

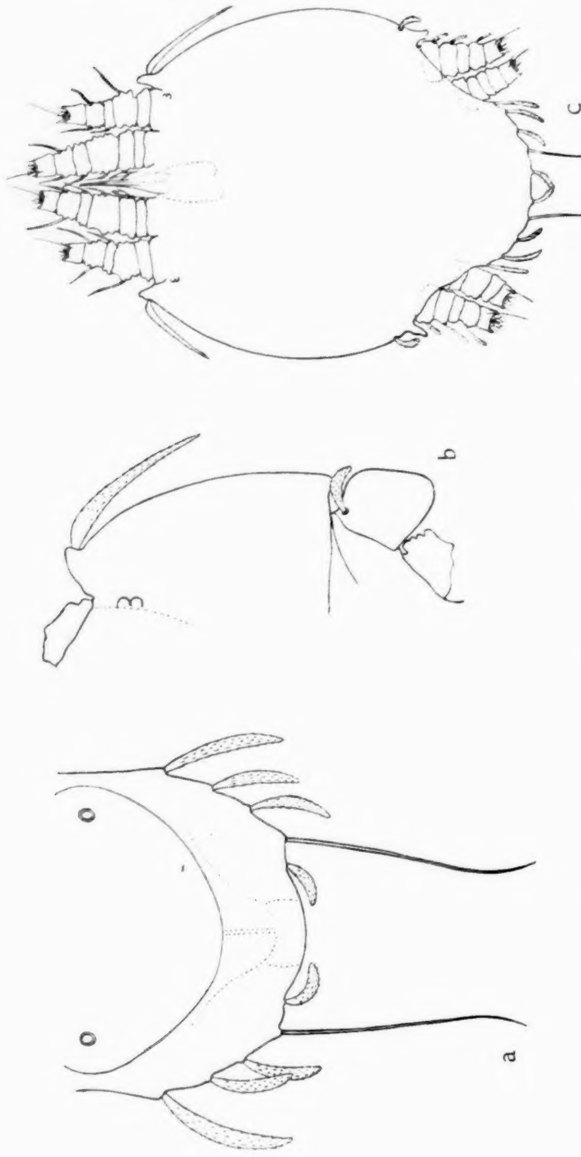

FIG. 1.—*Tenuipalpus micheli* Lawrence. ♀: *a*, dorsal surface of opisthosoma; *b*, anterior half of lateral margin of the body, enlarged; *c*, nymph, dorsal surface.

Dimensions.—Measurements of 3 specimens. Length, without mouth parts, 280–333 μ; width 260–277 μ.

Nymph (fig. 1, *c*).—The nymphal stage (probably just prior to the emergence of the adult) is characterised by several clear-cut features which differentiate it from the adult female. The following differences will be seen from fig. 1, *c*:—

(1) There is no transverse suture dividing the cephalothoracic and abdominal portions of the body (proterosoma and hysterosoma).

(2) There is a small angular projection on each side of the body just posterior to leg II and just anterior to leg III, but the small fin-like process just anterior to trochanter III in the adult is absent.

(3) The flagelliform setae along the posterior margin of the opisthosoma are shorter than in the adult.

(4) The legs are much shorter and proportionately thicker.

(5) A genital opening is absent or inconspicuous. One of the two nymphs mounted differs from fig. 1, *c* in having a wide flattened hair on the outer side of femur II, and, in addition, a long, partly flattened hair on the outside of patella II, this hair being absent in the nymph figured.

Dimensions of Nymph.—Measurements of 2 specimens. Length, without mouth parts, 225–300 μ; width, 190–232 μ.

Material.—3 ♀♀ and 2 nymphs from *Chaetacme aristata* Planch., Stella Wood, Durban, collected by M. Lavoipierre and R. F. Lawrence, July 1940. *Tenuipalpus micheli* is found only on the lower surfaces of the leaves of its host plant, which are smooth and shiny. It occurs on the whole surface of the leaf and is not found in such large numbers as *T. gibbus* n. sp. Its movements are sluggish, though not as slow as those of *T. quadrisetosus*. In life it is almost transparent and is of a greenish-yellow colour. All stages were found during July 1940 at Stella Wood, Durban, by the writer and M. Lavoipierre. The host plant, *Chaetacme aristata*, is a very large tree, common in the coastal scrub of Natal, Pondoland, and the Eastern Province.

Tenuipalpus quadrisetosus Lawrence (text-fig. 2).

T. quadrisetosus Lawrence, Journ. Ent. Soc. S. Africa, vol. iii, p. 114, text-figs. 6 and 7, 1940.

In the single ♀ specimen on which the original description was based the four long setae of the body had been broken (as was surmised in the description of the type). These are actually much longer than they appear in fig. 6 (*loc. cit.*). The figure in the present paper (fig. 2) represents the actual state of affairs in regard to the length of these setae, or flagellae as they may be more appropriately called. The anterior pair of flagellae are

longer than the posterior pair ($1\frac{1}{3}$ times) and also longer than the body measured from the apex of the mouth parts to posterior margin; they

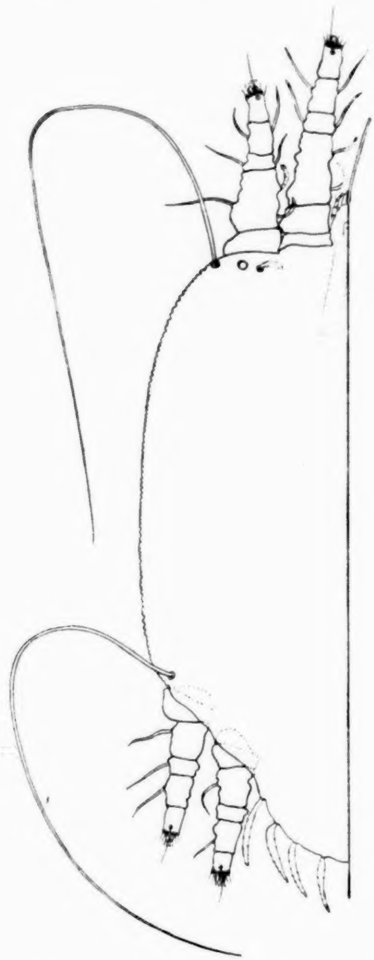

FIG. 2.—*Tenuipalpus quadrisetosus* Lawrence. ♀. Left half of dorsal surface showing the anterior and posterior flagellae.

are a little more than $3\frac{1}{2}$ times as long as leg I. The posterior pair are shorter than the body length (not including the mouth parts) and 5 times

as long as leg III. There is otherwise nothing to add to the description of this very peculiar and characteristic species.

Dimensions.—Length, without mouth parts, 322 μ; width, 220 μ.

Nymph.—The nymph differs from the adult only in its considerably smaller size, and in the corrugations of the body, which are much fewer and more coarse than those of the adult. There is a large, more or less oval, smooth area just behind the mouth parts on the dorsal surface from which corrugations are entirely absent.

Dimensions of Nymph.—Length, without mouth parts, 248 μ; width, 218 μ.

T. quadrisetosus is found on both the upper and lower surfaces of the leaves of the host plant, though usually on the upper surface. It appears to prefer the region of the mid-rib of the leaf and was also seen on the petiole. It moves more slowly than any other South African species of *Tenuipalpus* and its movements can be described as hardly perceptible. In life it is rust-red in colour. The host plant, *Cryptocarya woodii* Eng. (Family Lauraceae), is a small tree found along the coast and in the Midlands of Natal and the Eastern Province.

Material.—1 ♀, Stella Wood, Durban (M. Lavoipierre and R. F. Lawrence, July 1940); 1 ♀, Karkloof, near Pietermaritzburg (B. Rycroft and M. Lavoipierre, April 1941). From *Cryptocarya woodii* in both localities. At Durban a large number of cast skins resembling the adult form in every detail were found attached to the leaves of the host plant.

Tenuipalpus australis Tucker.

T. australis Tucker, Union of S. Africa, Div. of Entomology, Mem. V, p. 3, pl. 1 and pl. 3, figs. C–J, 1926.

The species is very common at Durban and is probably extremely widespread in Natal. It was found living in considerable numbers both on introduced plants in the Botanic Gardens at Durban and on indigenous shrubs growing along the north coast of Natal. There can be no doubt that Tucker's species is extremely similar to Geijskes' *T. phoenicis*. On examining the type specimens of *T. australis* it was found that they agreed in nearly every respect with the detailed figures of *T. phoenicis* given by Geijskes in his description of the type (1). This was especially marked in the case of the ventral surface, the proportions and shape of the two abdominal plates being identical in the two species, while the arrangement of the various spines on the ventral surface was the same. In only one detail does this agreement seem to be lacking, the postero-lateral margin of the abdomen being provided with 3 dorsal hairs in *phoenicis*, while there are 4 in *australis*. In *australis* the hair on the dorsal surface of the anterior

femora is slightly expanded and spiculate, though shown as a simple setiform hair in Tucker's figure. Even the detail of the reticulate sculpture of the ventral and dorsal surfaces is the same in the two species.

It seems extremely unlikely that *T. australis* is an indigenous South African species, judging by its wide distribution in South Africa and the facility with which it is able to live on both introduced and indigenous plants. It is recorded by Tucker as living on citrus fruits in the Cape Province, Transvaal, and South Rhodesia, as well as in Natal (3).

If *phoenicis* and *australis* are the same species, and I strongly suspect that they are, Tucker's *australis* has priority and *phoenicis* becomes a synonym thereof. Both forms, however, may prove to belong to an older previously described species, in which case they will both lose their present identity. Geijskes in his excellent paper on the European Tetranychidae records *T. phoenicis* from *Phoenix* palms growing in hot-houses in Holland. He thinks, however, that the species may have its origin in the Mediterranean region, with a *Phoenix* species as the host plant. From this region the species may have spread with its host plant to various parts of the world, including South Africa and Holland; it is doubtless to be found now in many of the warmer regions of the globe. It is noteworthy that the five species of *Tenuipalpus* recently described by the writer from indigenous trees in Natal are all confined to a single host plant and have been found on no others. *Tenuipalpus australis*, on the other hand, appears to have been able to adapt itself to a number of trees and shrubs, both native and foreign. It has been found on the following host plants in Natal in addition to citrus fruit trees:—

Indigenous.	*Introduced.*
Osteospermum monoliferum L., Umhloti, Natal.	*Datura stramonium* var. *metel* L., Durban.
Barringtonia racemosa Roxb., Umhloti, Natal.	*Cistrum elegans*, Durban.
Coccinia palmata Cogn., Durban.	*Bixa orellana*, Durban.
Rhus laevigata L., Pietermaritzburg.	
Polygala virgata Thb., Karkloof, Pietermaritzburg.	

Tenuipalpus podocarpi n. sp. (text-fig. 3).

Types.—Numerous males, females, and nymphs from *Podocarpus falcata* (Thb.) R. Br., Cathkin Peak, Drakensberg Mts. (R. F. Lawrence, May 1941).

♀ *Colour.*—Light yellow, the specimens almost completely transparent.

Dorsal surface as in fig. 3. This species closely resembles *T. micheli*, but differ from it in several important details as follows: The total length considerably greater than width of the cephalothoracic portion, in *T. micheli* the total length is only a little greater than its width. Opisthosoma much

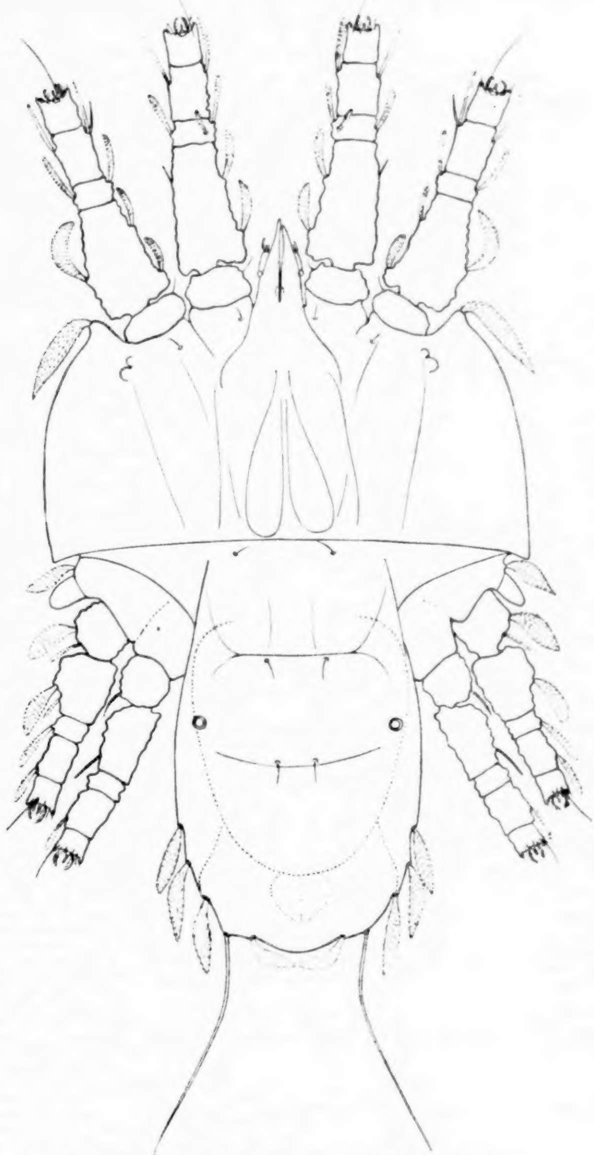

FIG. 3.—*Tenuipalpus podocarpi* n. sp. ♀. Dorsal surface.

longer than in *T. micheli*, jutting out far beyond the posterior legs, in *micheli* it just reaches as far as the posterior legs; the opisthosoma also much longer than wide in *podocarpi*, but considerably wider than long in *micheli*. The hair at the antero-lateral angles of the cephalothorax shorter than in *micheli*, distinctly less than half the distance between the anterior margin of cephalothorax and the transverse suture (propodosoma) measured at the side, while in *T. micheli* it is a little more than half this length. The small lateral fin-like process between the transverse suture and leg III, quite differently shaped, being conical, while in *micheli* it is broadly quadratiform (cp. figs. 1, *b* and 3).

Ventral surface resembling that of *T. micheli*, the pair of long median spines at the level of coxa III considerably further from each other than is the case in *T. micheli*; another pair of much shorter spines in the middle about half-way down the dotted oval (fig. 3), and a curved row of 4 equidistant spines along the inner posterior margin of the dotted oval; the genital opening (seen in dotted outline, fig. 3), with 4 spines, the posterior much longer than the anterior ones.

Nymph.—Resembling that of *T. micheli* closely except that the anterolateral hair is shorter and the corrugations of the body are fewer and much coarser.

♂. Among the specimens mounted are a number which differ from those which I have described and figured as female. They are more slender and the propodosoma is not as wide compared with the opisthosoma. These I take to be males; their colouring is consistently different from that of the females, being red and far less transparent. On measuring the propodosoma it was found that while the length was the same in both sexes, the width was far greater in the females, being to the length as 13 : 7, while in the males this was only 10 : 7. The length of the most anterior of the three flattened hairs, at the side of the opisthosoma, is considerably shorter compared with the hair next to it than in the females. The characters which distinguish the males from the females are therefore (*a*) the difference in colouring, (*b*) the narrower propodosoma, (*c*) the anterior flattened hair at the side of the opisthosoma which is shorter.

Dimensions.—♀. Measurements of 4 specimens. Length, without mouth parts, 344–378 μ; width, 254–260 μ; length of propodosoma, 130–147 μ. ♂. Measurements of 2 specimens. Length, without mouth parts, 333–361 μ; width, 200 μ; length of propodosoma, 135 μ.

Nymph.—Length, without mouth parts, 300 μ; width 209 μ.

Tenuipalpus gibbus n. sp. (text-figs. 4 and 5).

Types.—3 ♂♂ and 7 ♀♀ from the leaves of *Cryptocarya woodii* Eng., Stella Wood, Durban (R. F. Lawrence and M. Lavoipierre, July 1940).

♀. Colour dirty white, the hairs of the dorsal surface dull lilac, a sac-like hump on the dorsum of abdomen darker than the rest of the body.

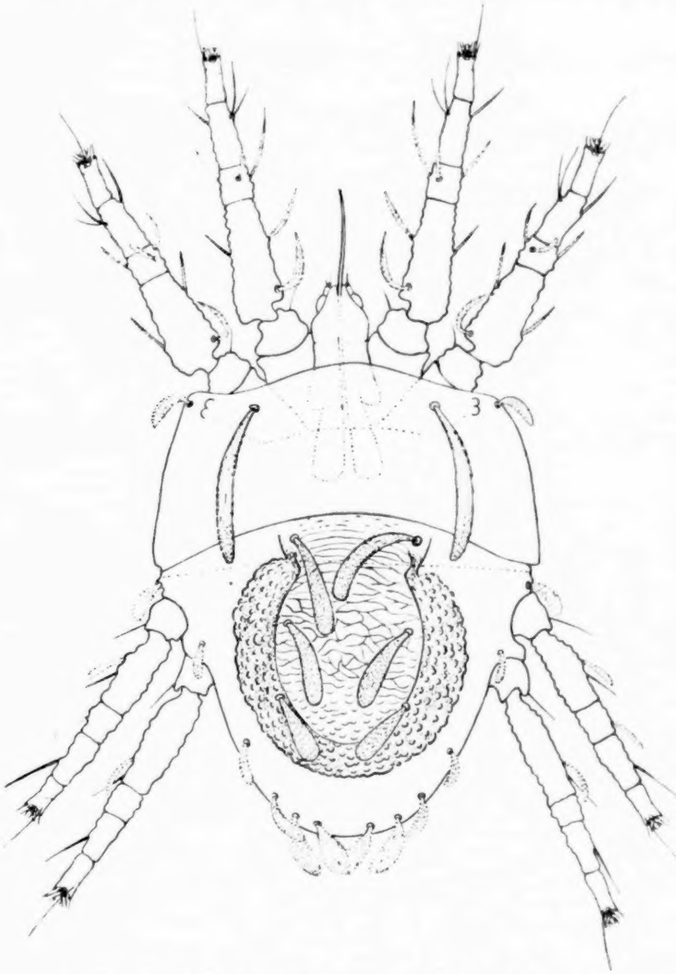

FIG. 4.—*Tenuipalpus gibbus* n. sp. ♀. Dorsal surface.

Dorsal Surface.—As in fig. 4, with 8 long spiculated leaf-like hairs, the two on the propodosoma unusually long. In the middle of the body posterior to the transverse suture an extraordinary hump standing out

from the back of the mite. It appears to be a sac, the darker marginal portion evidently caused by the doubling over of the sides. Seen from

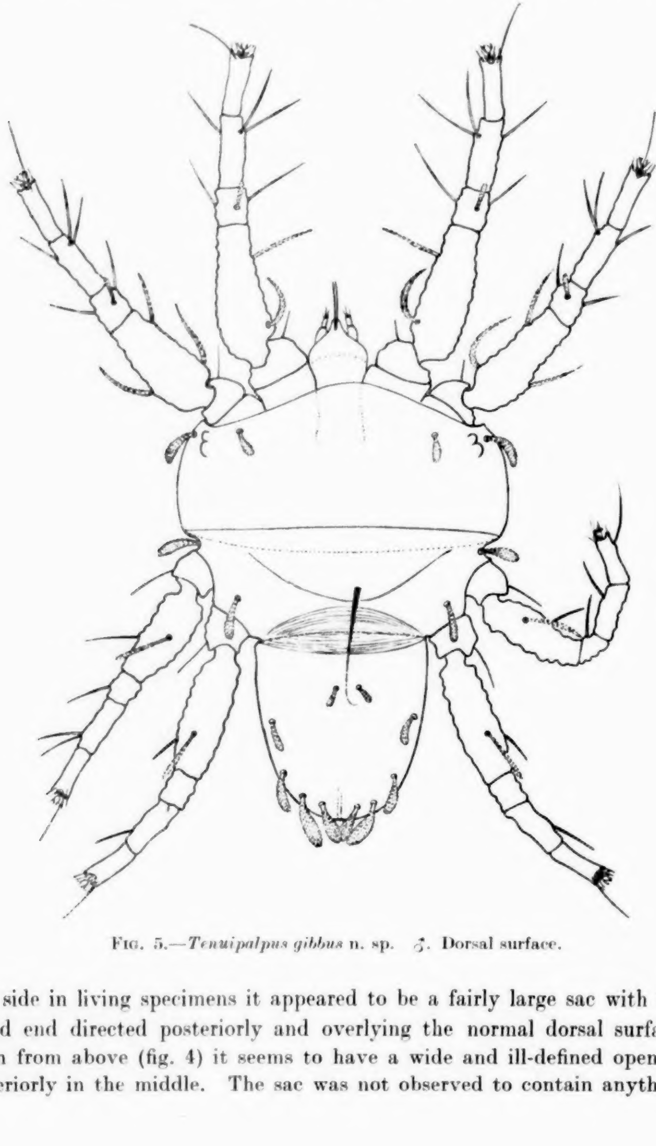

FIG. 5.—*Tenuipalpus gibbus* n. sp. ♂. Dorsal surface.

the side in living specimens it appeared to be a fairly large sac with the blind end directed posteriorly and overlying the normal dorsal surface. Seen from above (fig. 4) it seems to have a wide and ill-defined opening anteriorly in the middle. The sac was not observed to contain anything

and its function is entirely unknown. The legs longer and much more slender than is usual in mites of this genus.

Ventral Surface.—Spination as follows: A small spine at each of the anterior angles of coxa I and II, a very long slender spine near the basal junction of coxa I and II. A pair of small widely separated spines in the middle of the body just anterior to the transverse suture. Coxa III and IV each with a slender spine. In the middle of the hysterosoma, the area covered by the lighter inner portion of the sac with 4 slender spines, consisting of a large pair anterior to the middle of this area and a smaller pair near its posterior end. Posterior to these, two procurved rows of 4 spines each, the middle pairs a little further from each other than from the lateral spines, the posterior row wider and more strongly procurved than the anterior row. Femora I and II with a slender simple spine in basal half, all tibiae (penultimate segments) with a pair of short subapical spines.

♂. *Dorsal surface* as in fig. 5, with two distinct sutures dividing the body into three well-marked areas. Penis distinct, seen through the transparent cuticle. The legs much longer and more slender as compared with the ♀.

Ventral Surface.—Spination in general resembling that of the female; opisthosoma with 4 spines, the anterior pair (at about the level of the posterior suture) longer and more than twice as far from each other as is the posterior pair; genital aperture a longitudinal median slit at the posterior apex of the abdomen bordered by a longitudinal row of 3 small spines on each side. Femur I with 2, femur II with 1 fine smooth spine below; tibiae with 2 small subapical spines.

Dimensions. ♀. Measurements of 7 specimens. Length, without mouth parts, 245–271 μ; width, 193–200 μ. ♂. Measurements of 3 specimens. Length, without mouth parts, 230–245 μ; width, 166–180 μ. Total length with legs extended, ♀ 400–420 μ; ♂ 440–486 μ.

This species occurs on both surfaces of the leaf of the host plant and is not confined to any special part of it. It is found in far larger numbers than *micheli* or *quadrisetosus* and its movements are much faster than either of these species; the male is particularly active. No pre-adult stages were found. Two female specimens were taken from *Cryptocarya woodii* Eng. at Karkloof, near Pietermaritzburg (B. Rycroft and M. Lavoipierre, April 1941). It is noteworthy that this indigenous host plant is thus far the only one in South Africa known to harbour two entirely different species of *Tenuipalpus*.

Tenuipalpus natalensis n. sp. (text-fig. 6).

Types.—A number of presumably female specimens taken on *Halleria lucida* L. at Karkloof, near Pietermaritzburg (M. Lavoipierre, April 1941).

Colour.—Red or reddish-yellow, semi-transparent.

Dorsal surface as in fig. 6, *a*. Body oval with a distinct constriction posterior to the last pair of legs; anterior margin of body with a roughly

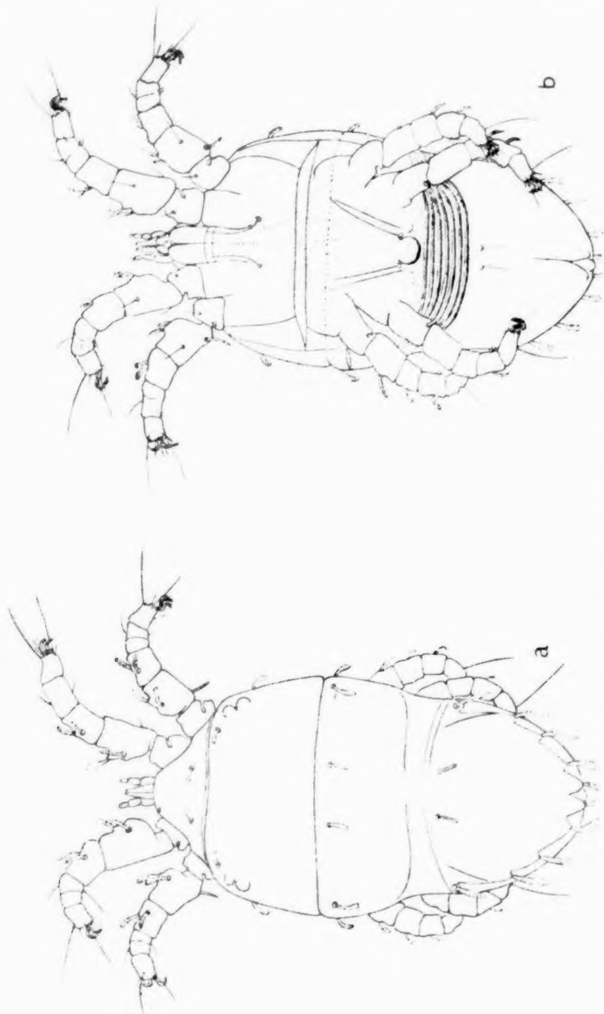

FIG. 6.—*Tenuipalpus natalensis* n. sp. ♀. *a*, dorsal surface; *b*, ventral surface.

triangular, transparent hood overlying the mouth parts and basal segments of the legs; eyes large; transverse suture distinct; lateral margins of the

opisthosoma with 4 large hairs on each side and a smaller pair at the posterior apex in the middle. The body, especially in its anterior two-thirds, entirely covered with a network sculpture consisting of small, more or less quadratiform segments; this sculpture absent on the narrow transverse band in the region of the constriction posterior to leg IV. Legs short, the anterior femora and to a less extent the anterior patellae with rounded knob-like processes, bearing short flattened hairs. *Ventral surface* as in fig. 6, *b*, characterised by a transverse procurved band of about 7 strong chitinous ridges extending across the abdomen, these ridges a conspicuous feature of the ventral surface and absent from the dorsal surface; anterior to this band a pair of long slender spines between legs IV; posterior to it a pair of similar but much smaller spines, closer to each other than are the two larger spines; a long slender spine at the base of coxa I. Legs with unusually large claws, the tarsi with two sensory hairs, the more proximal of these the longest, these hairs apparently considerably longer than in other species of the genus. The two abdominal plates near the posterior end of the body absent or inconspicuous.

In general the distinctive characters of this species appear to be as follows: Legs short, the femora with round knob-like processes; claws of tarsi long and strong, the sensory setae of the tarsi very long. Ventral surface with a transverse band of about 7 chitinous ridges posterior to leg IV. Body with a distinct constriction posterior to leg IV. Lateral hairs of opisthosoma unusually large. Body size small.

There are no differences of structure in the six specimens before me which could be regarded as sex characters. I am therefore unable to say to which sex the types belong.

Dimensions.—Measurements of 5 specimens. Length, without mouth parts, 200–226 μ; width, 114–136 μ; total length, including anterior legs, 280–316 μ.

This species occurs quite commonly on *Halleria lucida* L. Its movements are as fast as those of *T. australis* Tckr. Most of the individuals, however, appeared to be quiescent. The intravascular tissue of certain parts of some of the leaves of the host plant had dried up, and many of the quiescent forms were found in this situation, where they seemed to derive some protection from the skeletal structures of the leaf.

Remarks on the Genus TENUIPALPUS.

It appears to the writer that the genus *Tenuipalpus*, as it exists at the present time, embraces a number of rather heterogeneous forms, which it would be simpler to separate into at least two genera. Donnadieu, the creator of the genus in 1875, did use another genus, *Brevipalpus*, for

some of his species which were later replaced in the genus *Tenuipalpus*. I have unfortunately not been able to see his paper (4) which forms the basis of our knowledge of the group, but from a consideration of the species redescribed and figured by Geijskes (1) and those previously described by the present writer (2) from South Africa, together with those of the present paper, a division of the genus would appear to be highly necessary. For instance, a glance at the excellent figures which Geijskes gives of four species of the genus makes it obvious that *T. orchidarum* Parfitt could hardly belong to the same genus as *T. oudemansi*, *T. phoenicis*, and *T. cactorum*. *T. micheli*, described by myself in a previous paper (2), and *T. podocarpi* of the present paper, should be placed in one genus with *T. orchidarum*; *T. phoenicis*, *T. cactorum*, *T. australis*, and *T. natalensis* of the present paper should certainly form another distinct genus, with *T. geisenheyneri* Rübsaamen (6) and probably a number of American species included as well. In which of these two groups Donnadieu's five species should be placed, or those described from Europe by Canestrini and Fanzago (5), I am unable to say, but this could be left to those conversant with the older literature. A further genus would have to be created for *T. quadrisetosus* Lawrence, and possibly another for the species which I have described in this paper as *T. gibbus*. I doubt whether Tucker's *T. ornatus* rightly belongs to this genus at all. Approximately 23 species of the genus *Tenuipalpus* have previously been described from Europe, North and South America, South Africa, and Malaya. It seems that indigenous species of *Tenuipalpus* are always found on indigenous host plants and will usually be confined to a single one, while introduced species will occur on a large and mixed assembly of native and foreign plants. They are especially liable to be spread to other countries by means of domesticated plants such as the commoner kinds of fruit tree, for example citrus. They have hitherto been found on citrus trees in three continents—Europe, North America, and Africa.

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INTERESTING EARLY JUVENILE STADIA OF CERTAIN WELL-KNOWN SOUTH AFRICAN FISHES.

By J. L. B. Smith.

(With three Text-figures.)

(Read March 18, 1942.)

During a revision of the Sparid fishes of South Africa (Smith, Trans. Roy. Soc. S.A., 1938, vol. xxvi, pp. 225–305), the genus *Chrysoblephus* Swainson, which had not been accepted by most workers, was restored to full rank. In that genus were placed four well-established species, as well as two others which had not been accepted by Barnard (Ann. S.A. Museum, 1927, vol. xxi, pp. 698 and 700). These, *puniceus* G. and T. and *lophus* Fowler, were found to be valid species and to fall in *Chrysoblephus*. The case of *C. puniceus* (G. and T.) was particularly interesting because of the close relationship of that Natal species with *C. cristiceps* (Cuv.) of the southern Cape. The two species evidently have similar habits and the same type of habitat, *i.e.* rocky shelves or reefs in fairly deep water, but there is an almost sharp line of demarcation between the areas where they occur. *C. cristiceps* is typical of the southern Cape, extending from Cape Town eastwards to East London, becoming rapidly less frequent farther north, and being comparatively scarce at Durban. *C. puniceus*, on the other hand, is found only very seldom south of the Kei River, and has recently been observed (Smith, Trans. Roy. Soc. S.A., 1940, vol. xxviii, p. 176) to become progressively more abundant, and of greater average size, as far north as Beira.

In only very few cases is anything known about the reproduction or the developmental stadia of even our commonest fishes of angling or commercial importance, which live in or about reefs in fairly deep water. Recently the cold current (temperature 10° C.) which occasionally appears off the coast of Knysna, and which causes high mortality among small and juvenile fishes, has enabled me to secure hitherto unknown stadia of several well-known species. In particular this material covers juveniles of *Chrysoblephus puniceus* (G. and T.) and of *C. cristiceps* (Cuv.), which differ most markedly from the adult stage in the markings on the body. The juveniles show clearly not only how closely the two species are related, but

also that they are clearly distinct. It may be noted that in view of the distribution of the adult, the appearance of the juvenile *puniceus* at Knysna is remarkable, but whereas many hundreds of juvenile *cristiceps* were thrown up, only two specimens of *puniceus* were found. In both cases the striking difference in markings from the adult is worthy of special note.

Chrysoblephus cristiceps (Cuv.).
(Text-fig. 1.)

Smith, Trans. Roy. Soc. S.A., 1938, vol. xxvi, p. 264, pls. xx and xxvi, and text-fig. 14.

Early Juvenile Stadia.—Proportions given in brackets are those of the adult stage.

Body oblong-ovate, highly compressed. Dorsal profile gently undulate, very slightly concave at nape. Depth 2·3 (Ad. 2·2), length of head 3·1 (2·9)

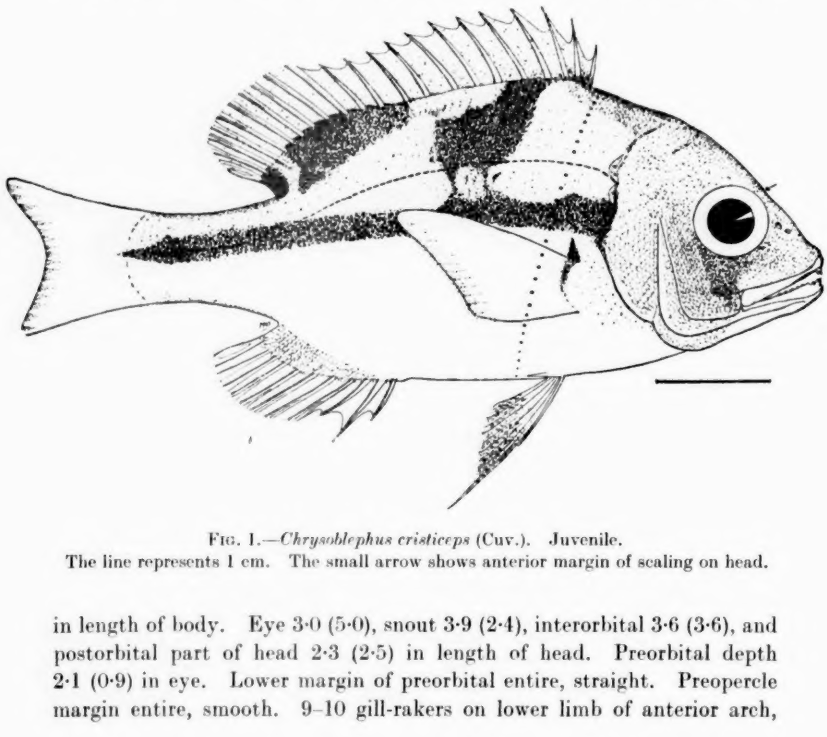

FIG. 1.—*Chrysoblephus cristiceps* (Cuv.). Juvenile.
The line represents 1 cm. The small arrow shows anterior margin of scaling on head.

in length of body. Eye 3·0 (5·0), snout 3·9 (2·4), interorbital 3·6 (3·6), and postorbital part of head 2·3 (2·5) in length of head. Preorbital depth 2·1 (0·9) in eye. Lower margin of preorbital entire, straight. Preopercle margin entire, smooth. 9–10 gill-rakers on lower limb of anterior arch,

anterior rakers very short, increase graduated posteriorly. Posterior nostril only slightly oval.

Mouth moderate, terminal, jaws equal, maxilla extends to below anterior margin of pupil. Extremity of maxilla well exposed. Anteriorly 6 acute canines in each jaw, outer on each side moderate, inner small. The inner series of molariform teeth characteristic of the adult stage (2 series) are not developed. The outer lateral teeth (molariform in adult) in a single series are obtusely conical and somewhat uneven in size. These form a lateral cutting edge.

D XII, 10, spines fairly stout, 4th or 4th and 5th longest, 2·6 (2·4) in head. Soft rays longer than posterior spines, longest 2·0 in head, edge of soft fin gently convex. A III, 8, 2nd spine much longer and stronger than 3rd, soft fin gently convex. Pectoral 1·2 (1·1) in head, reaches to anal origin. Ventral 1·3 (1·5) in head, 1st ray filamentous, reaches beyond anal origin. Caudal feebly emarginate, emargination increases with growth.

Scales strongly ctenoid, l.l. 61, l.tr. 9/19. Lateral line tubes short and stout. 11 cheek scales. Interorbital scaly, scaling extends to above anterior margin of eye. Preopercle flange almost completely scaly, only extreme margin naked. Ctenae on scales much coarser than in adults. Soft dorsal and anal with heavy basal scaling extending 1/3 length of rays.

Colour.—Ground colour faint rosy. A black lateral stripe, about ½ eye diameter in width, from caudal base along middle of side to hind margin of opercle. A black anterior dorsal blotch from below the 3rd–5th dorsal spine broadening irregularly inferiorly and posteriorly, contracting below, and in most specimens joining the lateral stripe by a narrow isthmus below the 7th–8th dorsal spines. A second black cuneate dorsal blotch, twice as long as deep, extending along the bases of the three posterior dorsal spines and of the first six dorsal rays, which covers the basal scaly sheath of the soft dorsal. A posterior black dorsal blotch at the base of the last two dorsal rays. A very distinct black blotch in and upwards of the pectoral axil. Nape, interorbital, snout, and cheek dusky. Dorsal and anal faint dusky. Caudal with dusky margin. Pectoral light. Ventral dark-dusky. Iris bronzy. This colour pattern is invariable save in minutiae among many specimens.

Length.—50–70 mm.

Locality.—Shores of the Knysna estuary, thrown up dead, February 1941.

Common Name.—Dageraad (Cape generally).

These juvenile fishes were at first not easy to recognise as *cristiceps*, but detailed study leaves no doubt as to their identity. The striking colour-pattern differs markedly from that of the almost uniform adult,

in which only the posterior basal spot on the dorsal and the axillary pectoral spot persist. Other differences from the adult are to be found in the dentition, *i.e.* absence of interior molars, in the filiform first ventral ray, in the lesser emargination of the caudal, and in the stronger ctenation of the scales. Scales from various specimens (50–70 mm. length) show no sign of annulation in the circuli. This would indicate that fishes of that size are probably in the second year of growth. I have observed ripe females of *cristiceps* in October, which would appear to confirm this. These small fishes have never been observed in rock-pools over many years of collecting, so that it may be presumed that they inhabit reefs in deeper water (the adult habitat). The early larval stadia are unknown.

Chrysoblephus puniceus (Gilchrist and Thompson).

(Text-fig. 2.)

Smith, Trans. Roy. Soc. S.A., 1938, vol. xxvi, p. 265, text-fig. 15.

Early Juvenile Stadia.—Proportions given in brackets are those of the adult stage.

Body oblong-ovate, very compressed. Dorsal profile evenly convex from nape, snout steep. Depth 2·2 (2·0), length of head 3·2 (3·3) in length of body. Eye 3·0 (3·8), snout 3·7 (2·5), interorbital 3·3 (3·3), and post-orbital part of head 2·2 (2·7) in length of head. Preorbital depth 1·6 (1·0) in eye. Lower margin of preorbital entire, straight. Preopercle margin with signs of slight serrae round the angle. 14 gill-rakers on lower limb of anterior arch, anterior rakers very short, increase in length posteriorly. Posterior nostril oval.

Mouth terminal, small, jaws subequal, maxilla extends to below centre of eye. Maxilla largely concealed, extremity slightly exposed. In upper jaw anteriorly 4–6 acute caniniform teeth of moderate size, the outer 2 pairs subequal, the inner pair when 6 present very small. 6–8 similar anterior canines in the lower jaw, usually two very small symphysial teeth, the outer 2 on each side larger, subequal to those in the upper jaw. In one case on each side one smaller canine. On each side in each jaw a lateral series of obtusely conical teeth corresponding with the outer lateral molars of the adult. No inner molariform teeth, although faint granulations are visible on the inner upper surface of the dentary.

D XII, 10, spines fairly stout, 4th and 5th subequal, longest 2·1 (2·1) in head. Soft rays longer than posterior spines, longest 2·4 in head, edge of soft fin gently convex. A III, 8, 2nd and 3rd spines subequal, 2·6 in head. Soft fin gently convex. Pectoral 1·1 (1·2) times head, reaches to above the origin of the soft anal. Ventral almost length of head, reaches

beyond anal origin, 1st ray filamentous. Caudal slightly emarginate, emargination increases with age.

Scales strongly etenoid, l.l. 52, l.tr. $\frac{9}{18}$, lateral line tubes very short and stout. 8 cheek scales. Interorbital scaly, scaling extends to in advance of above anterior margin of eye. Preopercle flange scaly, only

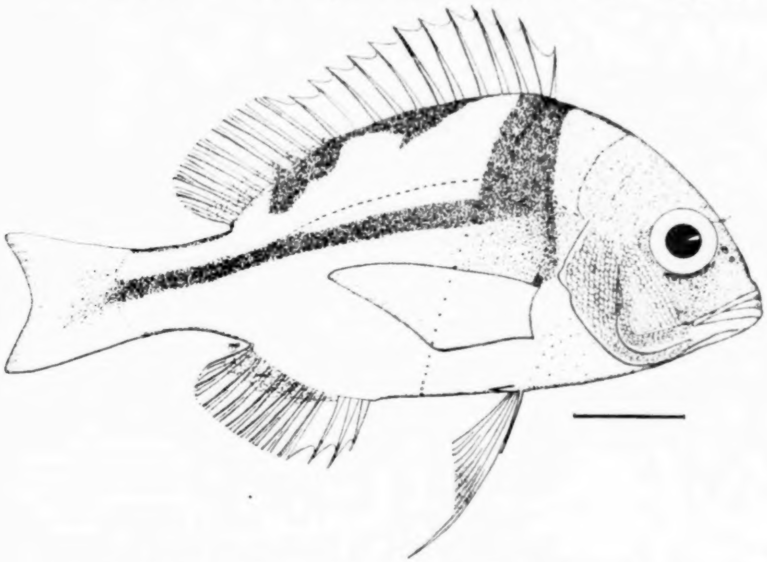

FIG. 2.—*Chrysoblephus puniceus* (Gilchrist and Thompson). Juvenile.
The line represents 1 cm. The small arrow shows anterior margin of scaling on head.

extreme inferior margin naked. Ctenae on scales relatively coarser than in adults. Basal scaling to soft dorsal and anal not very dense, not as heavy or of as great extent as in *cristiceps*.

Colour.—Ground colour faint rosy-pink. A black lateral stripe less than half eye-diameter in width from the middle of the caudal base forwards and slightly upwards along the side almost to the origin of the lateral line. At its anterior end it merges with the longer lower margin of an anterior trapeziform dark dorsal blotch which originates from slightly in advance of the dorsal, and extends to the base of the 3rd dorsal spine. The mark expands inferiorly. A second posterior irregular dark blotch runs along the dorsal profile from the base of the 4th–5th dorsal spine to the middle of the base of the soft dorsal, expanded postero-ventrally. Nape, snout, and cheek faintly dusky. A faint horizontal suborbital bar. Dorsal very faintly dusky marginally. Other fins light.

Length.—55–65 mm.

Locality.—Shores of the Knysna estuary, thrown up dead, February 1941.

Common Name.—Slinger (Natal).

It is remarkable to find these very young specimens some hundreds of miles south-west of the normal southerly limit of the area in which the adult of *puniceus* occurs. There is no question of their identity as *puniceus*. Although strikingly different from the adult in colour-pattern, every character of importance confirms them as that species. The colour-pattern is similar to that of *cristiceps*, but the anterior dorsal blotch is further forward and more regular in shape in *puniceus*, while the dark mark at the hind margin of the dorsal base, characteristic of *cristiceps* at all stadia, is absent. Besides the colour pattern, the young differ from the adults in various other features, *e.g.* dentition, filiform ventral ray, ctenation of the scales, and less deeply incised caudal. With age the body changes to the triangular shape of the adult with the nuchal region elevated.

In so far as may be judged from the scales these fishes are between 1 and 2 years of age.

Fowler (Proc. Ac. Nat. Sci. Phil., 1935, vol. lxxxvii, p. 390, fig. 23) listed a fish, 70 mm. in length, taken from the stomach of a "Steenbras" (Durban), as *Dentex filosus* Valenciennes. In 1938 (Trans. Roy. Soc. S.A., vol. xxvi, p. 298), not having seen an actual specimen, I considered Fowler's specimen to be more likely a juvenile of *Polysteganus undulosus* (Regan). Since I have seen the specimens described above, there is no doubt that Fowler's specimen was a juvenile *C. puniceus*, although his figure (*loc. cit.*) shows a body shape quite unlike that of my specimens. The markings are, however, quite definitely diagnostic.

Family DENTICIDAE.

Polysteganus undulosus (Regan).

Smith, Trans. Roy. Soc. S.A., 1938, vol. xxvi, p. 298, pls. xxi and xxviii and text-fig. 23.

This species, known by the common name of "Seventy-four," was at one time quite abundant in the Mossel Bay–Plettenberg area. In recent years it has become progressively scarcer, so that specimens are rarely encountered. It is therefore of considerable interest that relatively large numbers of juveniles, 45–60 mm. in length, should have been thrown up dead at Knysna during an onset of cold water (10° C.) in February 1941.

This species is easily recognisable at a glance by the 5–6 narrow longitudinal wavy blue lines along the sides, which are present in even the earliest stadia (45 mm. length). These juveniles differ from the adults

chiefly in the following characters: the median blue-black blotch on the lateral line observed in later stadia is not present in small juveniles. The body of the juvenile is relatively more elongate, the dorsal profile much flatter, and the snout more sharply conical than those of the adult. The caudal is much less deeply excised in the juvenile. The preopercle flange is smooth in all stadia. The chief changes with growth are a gradual elevation of the nuchal region, producing a deeper body and a steeper snout, even to the extent of a frontal gibbosity in large adults. The caudal becomes more deeply forked with age.

Family DICHISTIIDAE.

Dichistius capensis (C. and V.).

(Text-fig. 3.)

Smith, Trans. Roy. Soc. S.A., 1935, vol. xxiii, p. 269, pl. xiii.
Ibid., 1938, vol. xxv, p. 389, pl. x (early post-larval stadium).

Nothing was known about the early stadia of this species until the post-larval specimen, 22 mm. in length, was described (above). Since that time other graduated specimens have been obtained which show the transition to the adult stage. Unfortunately specimens are obtained only by chance so that the complete transition could not be shown in one paper. The following is a description of a specimen, 36 mm. in length. Considerable changes have occurred when compared with the 22-mm. stage. Dorsal profile moderately steep, evenly convex from nape. Body elongate-oval, highly compressed. Depth 2·4, length of head 2·9 in length of body. Eye 2·6 in head. Preorbital depth 2·1 in eye. Preopercle margin strongly serrate, with two largest spines at angle.

Mouth terminal, small, horizontal, lower jaw projects slightly. Maxilla well exposed, extends to below anterior margin of eye. In the upper jaw the anterior teeth are almost exsert, rather elongate, curved, acute, incisiform, about 14 in the outer series. Behind the outer series are 2–3 rows of smaller similar teeth in an anterior patch. In the lower jaw the teeth are almost exsert and oblique, and the anterior teeth across the symphysis are elongate and incisiform, but not as acute as those in the upper jaw. There are 12 larger teeth anteriorly, and on each side 5–6 smaller fine teeth laterally. Behind the anterior teeth no other teeth can be observed. Gill-membranes scarcely united, free from isthmus.

D X, 18, 4th spine longest, 2·5 in head, 9th and 10th spines subequal, 2/3 of 4th. First ray twice length of last spine, the anterior rays elevated, forming a lobe. Edge of soft fin undulate, concave behind anterior elevation. As compared with the 22-mm. stage, the spinous dorsal is

unchanged, whereas the anterior soft rays are relatively longer. A III, 13, anterior rays elevated, 1·8 in head, forming a lobe. Edge of fin gently concave. Pectoral 1·4, ventral 1·5 in head, latter does not reach vent. Caudal slightly emarginate. Scales very thin, almost impossible to count with accuracy. Basal scaling of dorsal and anal much less than in adult stage, not 1/5 of total height of rays.

Colour.—Predominantly dark-dusky above, silvery grey below, each area produced to form alternate dark and light cross-bars. From the

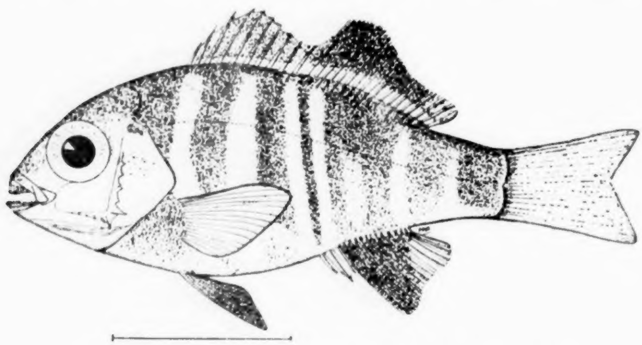

FIG. 3.—*Dichistius capensis* (C. and V.). Juvenile. 36 mm. The line represents 1 cm.

snout to the origin of the dorsal fin is dark, thereafter alternated 6 light and 6 dark cross-bars, the light cross-bars extending just short of the dorsal profile, and most of the dark bars just short of the ventral. The fourth dark cross-bar is the widest, and is continuous over the anterior part of the anal fin. (This pattern is slightly different on the other (r.h.) side of the specimen, the bars varying in width.) Dorsal distally dark, with a light bar running along the base of the spines and rays just above the body. The anterior rays darkest. Anal anteriorly very dark, only the few hinder short rays light. Pectoral and caudal light. Ventral dark.

Locality.—Cape Seal. A rock pool at low tide mark, early December 1941.

The 22-mm. stage described earlier (Smith, 1938, *loc. cit.*) was presumed to be about 6 weeks old, having been taken in September. The 36-mm. stage described above, taken in early December, is probably about 3½ months old. Very considerable growth changes have taken place from the 22-mm. to the 36-mm. stage. The body has deepened, with great alteration in the shape of the head, the mouth has changed from oblique to horizontal, the earlier cuspidation of the incisors has disappeared, the

caudal has become more deeply emarginate, and the anterior dorsal and anal rays more elevated. The 36-mm. stage is much more like the adult, differing chiefly in the presence of the preopercular spines, in the less deeply incised caudal, and in the lesser elevation of the soft dorsal and anal rays. The teeth are much more acute than those of the adult.

A specimen 58 mm. in length was obtained in the same locality (Cape Seal) in April. The chief variations from the 36-mm. stage are: the anterior dorsal and anal rays are more elevated, the caudal is more deeply forked, the anterior incisiform teeth have the distally dilated curved shape of those of the adult, and the preopercular spines are markedly smaller, though very distinct, and the body is deeper, 2·3 in length. The body bears 8 dark cross-bars alternated with light areas of equal width.

The principal growth changes in *Dichistius capensis* may thus be summarised:

	22 mm.	36 mm.	58 mm.	Adult up to 500 mm.
Depth in length .	2·9	2·4	2·3	2·2
Eye in head . .	2·5	2·6	3·0	3·8–5·0
Preopercle margin .	Strongly serrate.	Serrate.	Serrate.	Smooth.
Caudal . . .	Truncate.	Feebly emarginate.	Emarginate.	Deeply emarginate.
Anterior dorsal rays in head.	3·5	2·3	2·0	1·7
Anterior teeth . .	Cuspidate.	Pointed.	Rounded.	Rounded.

I wish to express my gratitude to my wife for the illustrations and to the National Research Board for financial assistance.

Albany Museum,
Grahamstown,
February 1942.

THE ENERGY AND ENTROPY OF ACTIVATION OF THE REACTION BETWEEN THE PERMANGANATE AND THE FORMATE ION.

By L. M. Hill and F. C. Tompkins.

(Read April 15, 1942.)

The temperature coefficient of the velocity constant of a large number of reactions is well expressed by the Arrhenius equation, $d\, ln.k/dT = E/RT$, which can be written in the integrated form,

$$\log_{10} k = B - E/2{\cdot}303RT, \qquad (a)$$

if E is assumed to be independent of temperature. The integration constant B has therefore been called the temperature independent constant. Deviations from equation (a) have been found experimentally, which have been supposed to be due to such causes as the presence of impurities, or inadequate temperature control, because they have been of the order of the experimental error. Recently La Mer (1), using the statistical method of Tolman and defining the activation energy more precisely as the difference between the average energy of the reacting molecules and the average energy of all the molecules, has obtained the equation,

$$\log_{10} k = 1/(2{\cdot}303R)\int_0^T(\partial E/\partial T)dT/T - E/2{\cdot}303RT + C,$$

where C is an integration constant. The integral term has been called the entropy of activation by analogy with thermodynamics. In bimolecular reactions, where E is independent of the temperature, the integral term is zero and C equals $\log_{10} Z$, where Z is the collision frequency for unit concentration of reactants in units of reciprocal time. In general, however, B is composed of two terms, a collision frequency which varies as the square root of the absolute temperature and a factor involving $\partial E/\partial T$ for the process, inactive to active molecules. Since the value of $\partial E/\partial T$ depends on the difference of the product of the partial molal heat capacity of the critical complex and a term embracing its specific reactivity for its different energy states, and the sum of the partial molal heat capacities of the reactants (2), it is rarely zero. It is our purpose here to decide experimentally whether or not it is of measurable magnitude in the permanganate-formate reaction. A recent survey by La Mer and Miller (3)

shows that reactions in which a definite variation of E with temperature has been found to fall roughly into two categories, those involving a halogen compound and those in which either a hydrolytic or proton change occurs. It is of interest to extend these measurements to an oxidation-reduction reaction.

Furthermore, the dielectric constant and the molal volume of water are both functions of temperature and therefore the number of rate-determining collisions will be altered (*a*) through the operation of the primary salt effect and (*b*) because of the changes in electrical repulsion between the two similarly charged reactant ions. By incorporating such variations into the Brönsted-Debye-Hückel equation for low ionic strengths, it is found that the activation of the permanganate/formate reaction should increase for increasing concentrations of neutral salts.

The reaction, whose kinetics have been reported in an earlier paper (4), is suitable for the testing of these theoretical conclusions, since (*a*) the velocity constants may be determined accurately over a wide range of temperatures, (*b*) it is conveniently free from side reactions, and (*c*) it proceeds without change in ionic strength.

Experimental.

A full account of the iodometric method used, together with details on the elimination of errors associated with it, have already been given (4). The velocity constants given below have been calculated on the basis of the second order equation in which equivalent quantities of the reactants have been employed, the time being expressed in minutes and the concentrations in g. mols. per litre. The bimolecular rate constants increase slightly with time, particularly at the higher temperatures and higher ionic strengths, but the variation is linear over a sufficiently long period to permit of extrapolation to zero time. This is shown in Table I, where the change in velocity constant per unit time is seen to be constant within experimental error. The method of extrapolation has been previously adopted (5) in the iodide/persulphate reaction by a number of workers in order to eliminate the effect of the triodide formation and the increasing ionic strength during the course of the reaction and has proved acceptable. The variations in ionic strength have been obtained here by the addition of suitable volumes of M/30 potassium sulphate solution.

For the sake of brevity, Tables II and III contain summaries of the results obtained, and details of individual rate experiments have been omitted. It has been estimated that the probable error in the values of the velocity constants is of the order of 1 in 400, and consequently there is an uncertainty in E of the order of about 80 cals. and in B of about 0·06 unit.

TABLE I.

TEMPERATURE 24·85° C. IONIC STRENGTH 0·01212.
CONCENTRATION OF $KMnO_4$ AND NaCOOH 0·001651 M.

Time = t (minutes).	Vel. const. = k (G. mol. l. min.).	Δk.	$\Delta k/\Delta t$.
0	39·00		
		0·30	0·075
4	39·30		
		0·36	0·090
8	39·66		
		0·30	0·075
12	39·96		
		0·36	0·090
16	40·32		
		0·24	0·060
20	40·56		
		0·30	0·060
25	40·86		
		0·36	0·072
30	41·22		

TABLE II.

CONCENTRATION OF $KMnO_4$ AND NaCOOH 0·001651 M.

Vel. const.		Ionic strength.	E.	B.
24·85° C.	28·40° C.			
35·47	44·19	0·004122	11,620	9·91
37·40	46·67	0·008122	11,750	10·23
39·00	48·74	0·01212	11,825	10·30
42·30	52·90	0·02412	11,860	10·36
47·17	58·96	0·04412	11,850	10·40
49·50	61·95	0·08412	11,920	10·47

Table II gives the value of the velocity constant at two temperatures and at various ionic strengths, together with the calculated values of the heat of activation and the frequency factor B. There is a small but definite increase in both E and B with increasing neutral salt concentration. It is of interest to compare these values with those to be expected theoretically. Amis and La Mer (6) have found it expedient to decompose the entropy

of activation into three terms: (*a*) the entropy contribution for the reactants, assumed to be uncharged particles, (*b*) the contribution arising from the presence of charges on the reactant ions, and (*c*) the interaction contribution of the ionic atmosphere. La Mer and Kamner (7) have been able to derive equations for the contribution of the ionic atmosphere to B and E for low ionic strengths. These are

$$E/2{\cdot}3RT = -\frac{2Z_aZ_b\beta\sqrt{\mu}}{(DT)^{3/2}}\left(3/2\frac{ln.D}{ln.T}+\tfrac{1}{2}\frac{ln.V}{ln.T}+3/2\right)$$

and

$$S/2{\cdot}3RT = -\frac{2Z_aZ_b\beta\sqrt{\mu}}{(DT)^{3/2}}\left(3/2\frac{ln.D}{ln.T}+\tfrac{1}{2}\frac{ln.V}{ln.T}+3/2\right),$$

and by introducing Wyman's values for D and $ln.D/dT$ (8) and I.C.T. values of $d.ln.V/d.ln.T$ they obtain

$$E/2{\cdot}3RT = Z_aZ_bA_2\sqrt{\mu} \quad \text{and} \quad S/2{\cdot}3RT = Z_aZ_bA_3\sqrt{\mu},$$

where A_2 is 0·45, 0·52, and 0·60 and A_3 is 1·44, 1·53, and 1·64 respectively at 15°, 25°, and 35° C.

The initial rise found here from 11,620 to 11,750 cals. for E is greater than that demanded theoretically, and a similar deviation was found in the bromoacetate/thiosulphate reaction (7). As has been pointed out there, the probable experimental error is too large for the short interval to warrant any definite conclusions. In the present work, it is possible that the sulphate ion exerts a specific but small effect, particularly in view of the slope of 0·90 for the log k/ionic strength curves reported earlier (4), since the value of 11,620 cals. was obtained in absence of potassium sulphate, whereas that of 11,750 cals. was measured in presence of this salt. At higher ionic strengths, the experimental increase in E $\left(\frac{\Delta E}{\Delta\sqrt{\mu}} = 920 \text{ cals.}\right)$ approximates to that expected from the limiting law $\left(\frac{\Delta E}{\Delta\sqrt{\mu}} = 720 \text{ cals.}\right)$. Since E increases with neutral salt concentration, it might be anticipated that the rate constant should fall, but since the simultaneous increase in B is nearly three times more rapid, the rate is in fact higher. The frequency factor B consequently plays the predominant rôle in determining the magnitude of the primary salt effect, and means from the kinetic viewpoint that the number of rate-determining collisions is increased, possibly by the clustering of the reactant ions about the added potassium ion, thereby providing a greater opportunity for collision of the formate and permanganate ions.

In Table III are given values of the velocity constant at constant ionic strength at various temperatures. It includes the calculated values of

E and B. There is again a small but definite increase in both of these terms as the temperature is raised.

TABLE III

CONCENTRATION OF $KMnO_4$ AND NaCOOH 0·00165 M.

Temperature C.	Vel. constant.	E.	B.
24·85	35·47	11,620	9·91
28·40	44·19	11,820	10·04
31·42	53·75	11,870	10·09
34·80	66·75	12,110	10·25
40·10	93·48	12,340	10·42

With increase of temperature, the dielectric constant of water decreases and the repulsion force between two similarly charged ions would be greater. The activation energy will increase due to these coulomb effects. It is given by $dE = -328{\cdot}7 Z_1 Z_2 . dD/D_1 D_2 . r$, where Z_1 and Z_2 are the number of elementary charges on the reactant ions, r is the average diameter of the ions, and D_1 and D_2 the values of the dielectric constant at the two temperatures. The accurate application of this equation requires the temperature coefficient of the rate in isoelectric solvents, which in practice are impossible to use with permanganate as one of the reactants. Nevertheless, using Wyman's values for D and assuming with Amis (*loc. cit.*) a value of 2 Å. for r, the calculated increase is about 200 cals. as compared with about 500 cals. experimentally obtained for the same temperature range of 28° to 40° C. The agreement as to order of magnitude is satisfactory, since our measured temperature coefficients include not only the increased energy of the reactants due to pure thermal energy, but also the change due to the varying effect of the solvent on the reactant ions arising from the changed electrical forces in different dielectric media. Again, although E increases, due to a parallel but more rapid increase in B, the rate constant increases with temperature. The increase in B is probably due to solvation effects.

For reactions of ions, the polarity is high and the interaction of solvent and reactants will be large. When the ions are similarly charged, the critical complex is more polar and there will be an increase in the orientation of the solvent molecules attached to the ions. This causes an increase in order according to the transition theory (10), and therefore the entropy, and hence the frequency factor B, decreases. With increasing temperature and increasing thermal agitation, we may conclude that desolvation takes

place to some extent and B should increase, as has been found experimentally. Similarly with increasing concentration of neutral salt, it may be assumed that a certain amount of desolvation of the critical complex takes place, and thus the increase of B with increasing ionic strength may be explained. This type of treatment also leads to an increase of E, both with temperature and ionic strength. The co-operation of solvent molecules allows E to be distributed over a greater number of degrees of freedom, and the fraction of collisions possessing the critical energy will be larger. This will in effect lower the experimental value of E—consequently any process leading to desolvation, as increase of temperature or of ionic strength, should cause an increase in E, as found experimentally. It must be emphasised that the same qualitative conclusions can be reached by a purely electrostatic treatment and that the physical basis is fundamentally the same.

The effect of such considerations on the molecular statistics is that any solvation effect will lower the more predominant factor B, and therefore in reactions where the critical complex is more polar than the reactant ions (*i.e.* in reactions between similarly charged ions) the calculated value (based on non-solvation) should be higher than that found experimentally. This has been shown to be the case in the formate/permanganate reaction (4).

Summary.

The effect of the variation of ionic strength and of temperature on the heat of activation and the entropy of activation of the formate/permanganate reaction has been studied. Both these terms show a small but definite increase with increase of temperature, and neutral salt concentration and the variations found have been compared with approximate theoretical values based on the Brönsted-Debye-Hückel Law. A qualitative treatment from the viewpoint of solvation predicts the same conclusion, and reasons are given for the low values of the velocity constant given in a previous paper as compared with those calculated from molecular statistics.

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INTERESTING NEW FISHES OF THREE GENERA NEW TO SOUTH AFRICA, WITH A NOTE ON *MOBULA DIABOLUS* (SHAW).

By J. L. B. Smith.

(With three Text-figures.)

(Read May 20, 1942.)

Family GOBIESOCIDAE.

Eckloniaichthys, genus nov.

Body fairly elongate, head not broad, little depressed. Dorsal and anal fins sub-opposite, remote from caudal, of few rays, hind margins free from body. Posterior segment of disc without free anterior margin, the two segments connected by an isthmus. No opercular spine. Teeth all incisiform, uniserial in each jaw.

By the combination of the unusually slender body, anterior insertion of dorsal and anal, incisiform teeth, and absence of a free margin to the anterior portion of the posterior segment of the disc, *Eckloniaichthys* is clearly distinguished from all other genera. Its nearest ally appears to be *Trachelochismus* de Barneville, from New Zealand, which has a similar anterior insertion of the vertical fins, but which has a much more robust depressed body, and no incisiform teeth, while the posterior lobe of the disc has an anterior free margin.

Eckloniaichthys scylliorhiniceps, sp. et gen. nov. (fig. 1).

Body sub-cylindrical, at most but slightly depressed at nape, highly compressed posteriorly. Dorsal profile very gently sloping from nape, snout pointed in profile, shape of head distinctly "Selachian." Head fairly depressed, with interorbital only slightly convex. Skin rough, densely beset with fine tubercles which cover the whole head and body, and extend almost to the extremity of the caudal fin. Eye covered with skin, and better visible from below than from above.

Maximum depth at shoulder 7·2, length of head 3·7 in length of body. Eye 3·8, snout 3·2, interorbital 2·1, and postorbital part of head 2·2 in length of head. Maximum width of head 1·5, maximum depth of head 2·2 in length of head.

Nostrils fairly close together at the anterior margin of the orbit, the anterior with a plain circular pedunculate flap. Several series of distinct pores on head. Gill-membranes united, folded across throat, apparently quite free from isthmus.

Disc of two distinct portions, originates below an eye diameter behind orbit. Total length of disc 2·0 in head, and it is 1·5 times longer than wide. Anterior segment almost regularly hexagonal, slightly wider than long. Posterior segment about 1·3 times wider than long. The two segments

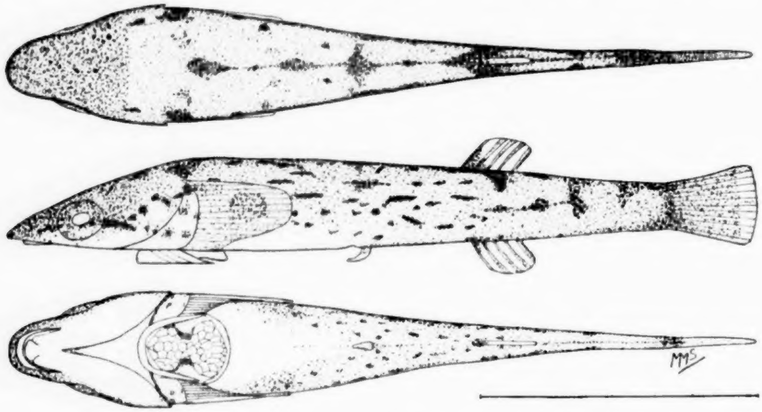

FIG. 1.—*Eckloniaichthys scylliorhiniceps* n.g. et sp.
Above: Dorsal view. *Middle:* Lateral view. *Below:* Ventral view.
The line represents 1 cm.

connected by an isthmus of moderate width. The floor of the disc is composed largely of horny plates of various shapes, mostly angular approximating to the hexagonal shape. Posterior segment of disc without anterior free margin. The hinder flange of the coracoid segment is continued forwards and upwards beneath the pectoral, being fused with the base of that fin for the basal two-thirds of its depth.

Mouth small, inferior, lower jaw entirely included in upper. The snout projects over the upper jaw in the form of a fleshy fold. There is a fairly thick plain continuous lip to the upper jaw. That of the lower jaw is trilobate, the central lobe being much the largest. The cleft of the mouth is almost rectangular, and extends 4·5 in the length of the head, about equal to the eye, and reaches below slightly beyond the anterior margin of the orbit. Teeth all incisiform. In the upper jaw there is a single series of about 14 slightly curved incisors, which become larger and slightly lanceolate anteriorly. No other teeth visible. From the symphysis

backwards there extends a ⊥-shaped narrow ridge which appears to bear minute asperities, but owing to the small size of the specimen this is difficult to establish. In the lower jaw a single series of 12 incisiform teeth which increase in length and are of more oblique insertion anteriorly. The anterior teeth are apically somewhat dilated with the upper edge cut to a very obtuse point, but they are not lanceolate. No conical teeth of any kind, nor any teeth behind the single outer series in each jaw.

D 5, inserted 2·2 times farther from the snout tip than from the caudal base, almost exactly midway between the hind margin of the head and the hind edge of the caudal. Base about 3·4 in head. The first ray does not appear to be articulated, but is quite soft. All the rays are simple. Hind margin of fin free from body. The 2nd and 3rd rays are the longest and sub-equal, about the length of the base of the fin. Edge of fin gently convex. A 5, inserted slightly behind dorsal, about midway between hind edge of caudal and pectoral base. In structure and size the fin is almost exactly the same as the dorsal. P 17, 6·0 in length of body, 1·9 in head. Base very heavy, extending over almost $\frac{3}{4}$ of the body depth. The upper longer portion of 11 simple rays, the lower shortened flange of 5 rays shortening ventrally, and all simple. There are 4 ventral rays, and no sign of a dorsally embedded spine. The hinder ventral ray extends almost to the posterior margin of the disc. Caudal rays 12, 7·7 in body length, 2·1 in head, almost truncate, with rounded edge, rays all simple.

Body entirely scaleless.

Colour.—When alive, dark green-brown, with a bar through the eye, and numerous red-brown streaks on the body. With preservation the colour changes to an orange-red, and the streaks to bright dark red. Ventral surface of head and disc light. Dorsal and anal light russet. Pectoral light distally. Caudal body colour with posterior light margin.

Length.—27 mm.

Locality.—10 miles west of East London.

Type, a male, apparently adult, in the Albany Museum.

This very interesting fish was taken among a dense growth of the sea-bamboo—*Ecklonia*—in a rock-pool at the lowest ebb of an exceptionally low spring tide. The colour pattern of the fish rendered it practically invisible in or on the *Ecklonia*. It is at first sight rather surprising that so sluggish a type of littoral fish should remain so long unknown. It is probably to be ascribed to the fact that this species doubtless never leaves the shelter of the sea-bamboos which generally extend little, if at all, above the lowest ebb of the tides. It may be noted that in the same pool in which this specimen was taken there were numerous specimens of *Chorisochismus dentex* Bl. Schn. on the rocks below. The incisiform teeth of *E. scylliorhiniceps* indicate a mode of life different from that of *C. dentex*,

which with its large conical teeth is obviously predatory and carnivorous.

Family GOBIIDAE.

Genus Taenioides Lacep.

An Indo-Pacific genus of degenerate forms, mostly quite blind, not previously recorded from South Africa.

The South African species, *jacksoni* n.sp., has two distinct dermal coverings. The outer envelops all the structures including the fins and the dermal bones of the head, and has obviously been developed in response to the mode of life of these creatures. Both skins bear chromatophores, but they are more plentiful in the inner coat.

Taenioides jacksoni sp. nov. (fig. 2).

Body elongate, eel-like, sub-cylindrical anteriorly, slightly more compressed in caudal region. Maximum depth at shoulder, body tapers regularly posteriorly. Head fairly compressed, interorbital only faintly convex. Depth anteriorly 11·2, length of head 7·1 in length of body. Depth at caudal base about $\frac{1}{4}$ depth at shoulder. Minute rudimentary obsolescent eyes beneath skin. Interorbital 5·5, snout 3·2, preorbital depth 6·0 and postorbital part of head 1·5 in length of head.

Numerous fine papillae or tentacles on head, longest on snout, above and around nostrils in small groups. A number in the preorbital and suborbital regions, the lower margin of the suborbital bearing a fringe of tentacles. A half-circle of 4–5 behind each eye. A group behind the hind end of the maxilla. Several scattered over the preopercle, the lower margin of which bears a fringe of papillae. A number on the opercle irregularly clustered towards the hinder lower region. A number of rather small papillae in a patch across the symphysis of the lower jaw. The lower margin of the ramus of the lower jaw bears an irregular fringe of somewhat larger tentacles. Of apparently numerous sensory canals on the head, an arborescent suborbital branch is most marked.

The externally visible outlines of the myomeres show from the shoulder, curving gently down to the middle of the side, thence to the caudal base. There are 25 simultaneous parallel superior and inferior retrorse branches which (except for those on the belly which do not reach the ventral profile) run to the dorsal and the ventral margins of the body. Before the apex of each furcation on the middle of the body is a vertical series of 3–5 fine cirri much like those of the head (fig. 2, C).

Mouth terminal, slightly oblique, lower jaw protrudes slightly. Maxilla exposed, extends just behind eye, total length from snout tip 2·4 in head

(3·4 in profile). Moderate curved fang-like teeth in apparently a single series round each jaw, difficult to count, about 20 in each jaw, longest scarcely 5 in maxilla length. No other teeth can be ascertained.

Gill-membranes broadly fused with isthmus. Gill-openings restricted to one lateral aperture, of vertical depth about 4 in length of head. Only

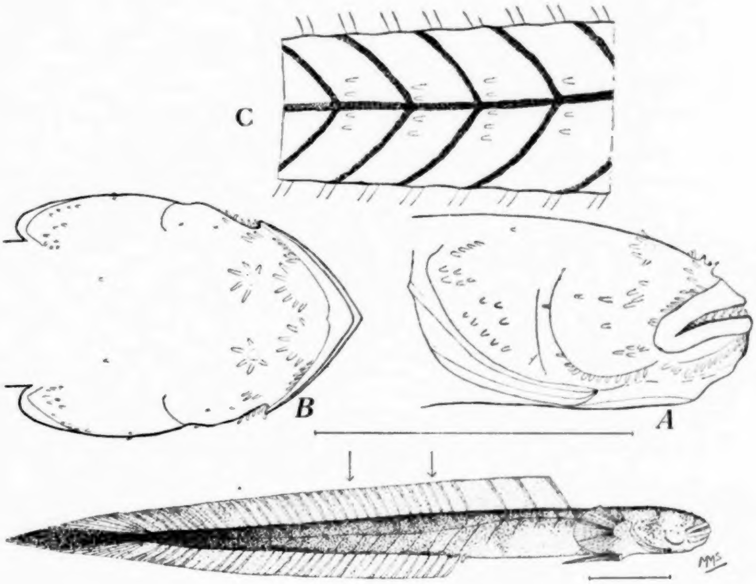

FIG. 2.—*Taenioides jacksoni* sp. nov.

Below: The complete animal, lateral view. The line represents 1 cm. The two arrows indicate the portion of the body shown enlarged in C above.

Above: The line represents 1 cm. A. Head, side view. B. Head, dorsal view. C. Side of body showing lateral tentacles.

3 branchiostegal rays visible. Gill-rakers small tubercles, increasing posteriorly, 7 on the lower limb of the anterior arch. Pseudobranchiae present.

Dorsal and anal confluent with caudal, rays covered by thick skin, very difficult to count or to examine. D 33–34, originates slightly in advance of hind margin of pectoral. First three rays widely spaced, about one-third head length apart, and from the fourth ray. Rays subequal, decrease very slightly posteriorly. Anterior rays 2·5 in head. A 30 inserted below the 4th dorsal ray, rays equally spaced, lower than the

dorsal rays, about 2·9 in head. Pectoral with lobate base, rounded, of 17 rays, 2 in head. Ventrals united, forming a disc, total length 1·2 in head. Caudal pointed, hastate, of 15 rays, 1·8 times head.

Scales entirely absent.

Colour.—Dark olive-brown, with close-set darker dendritic specks, densest dorsally, belly lighter. Fins lighter, greyish, except caudal, which is dark medially, lighter marginally. Myomere lines black.

Length.—Up to 90 mm.

Locality.—Shores of the estuary of St. Lucia, Zululand, living in burrows in the mud.

Type from St. Lucia in the Albany Museum.

Two specimens, one much shrunken, were obtained by Mr. W. T. Jackson, M.A., an enthusiastic and successful collector, after whom the species is named.

These peculiar degenerate blind Gobies have long been known from the tropical Indo-Pacific, and it is interesting to find a species on our shores. More intensive collecting will doubtless reveal that others are present also.

T. jacksoni appears to be clearly distinct from all other species by numerous features, notably in the nature of the dermal appendages.

Family BROTULIDAE.

This polymorphous family is fairly well represented in our waters, but it is only in recent years that the somewhat rarer forms with free caudal have been found here. The first to be described was *Bidenichthys capensis* Barnard, with lobate pectoral, and male organ without horny claspers. A specimen has recently been secured which appears to fall into the Australian genus *Dermatopsis* Ogilby, not previously found in South Africa. *Dermatopsis* is distinguished from *Bidenichthys* in that the pectoral fin is normal, and there are horny claspers in the male organ.

Dermatopsis kasougae sp. nov. (fig. 3).

Body fairly elongate, compressed, especially posteriorly. Snout blunt, almost cetacean. Dorsal profile gently sloping from nape. Depth 5·7, length of head 4·9 in length of body. Eyes small, lateral, covered by skin, 10·1 in head. Interorbital and snout sub-equal 5·0, and postorbital length 1·4 in head. The suborbital depth is slightly greater than the eye. Head fairly compressed, its greatest width one half of its depth. Head rather spongy and pitted, with small foliaceous lobes and convolutions about the snout. No barbels or cilia. Nostrils more or less tubular,

especially the anterior. Few distinct pores other than on the snout, but a few indefinite pits below the symphysis of the lower jaw. Preopercle margin beneath the skin. No obvious opercular spine, but a very obtusely angular hind margin well hidden by skin.

Mouth terminal, almost horizontal, jaws sub-equal. Maxilla extends almost two eye diameters behind eye, with a blunt spiniform projection on the lower margin near the hinder end. Teeth all acutely conical and fairly slender, all except those on the vomer are depressible. In the lower jaw the teeth form a band across the symphysis, in three series anteriorly

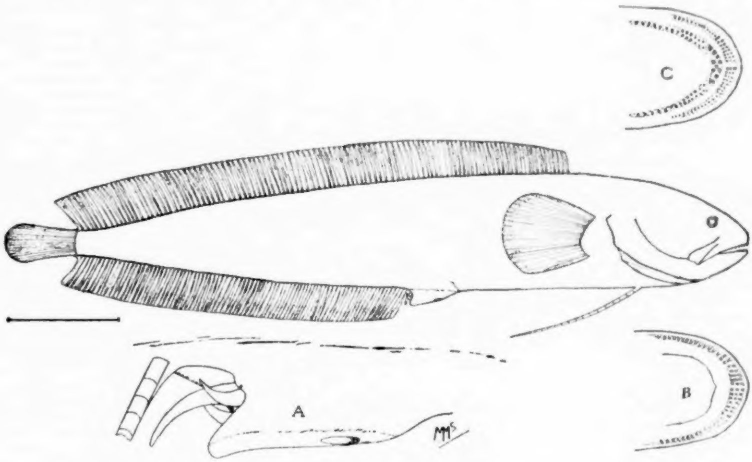

FIG. 3.—*Dermatopsis kasougae* sp. nov. The line represents 1 cm. A. Urogenital papilla, male, enlarged. B. Lower jaw, and C. Upper jaw, both enlarged, about × 4·2.

grading laterally to a single series which extends the full length of the dentary, about 42 in the outer series in all. In the upper jaw is a band of premaxillary teeth, triserial anteriorly, grading to a single lateral series, about 40 in the outer series in all. In the curved vomer are set 10 fairly large rigid conical sharp teeth. Each palatine bears anteriorly six rows of 2 teeth followed by a single series of 8. Pterygoids and tongue edentate. Tongue apically free, obtuse, with a median point.

Gill membranes narrowly attached to isthmus. Pseudobranchiae absent. A slit behind last gill. 12–13 gill-rakers on the lower limb of the anterior arch, merely low spiny tubercles.

The ventrals only are of simple rays, all other fin rays are divided. Dorsal and anal not confluent with caudal, but the basal axillary membrane

from the last ray of each attached narrowly to the base of the outer caudal rays. D 102, originates over the anterior third of the pectoral, almost three times farther from the hind margin of the caudal than from the snout tip. Base of dorsal 1·3 in length of body. The rays increase gradually posteriorly, the anterior being about 6·0, the posterior about 3·2 in length of head. A 86, originates almost exactly midway between the tip of the snout and the base of the caudal. Rays increase slightly in length posteriorly, the anterior being longer than the anterior dorsal rays, but the posterior are not as long as the posterior dorsal rays. P 22, 1·5 in head, tip reaches exactly half-way from the base of the fin to the origin of the anal fin. Each ventral of a single simple ray, as long as head, inserted twice as far from the origin of the anal as from the tip of the snout. Caudal free, rounded, 1·8 in head.

No trace of a lateral line can be discerned. The head is entirely naked. Minute very indistinct cycloid scales buried in a thick dermal layer over the whole body to the nape. It is only on the nape that they appear to be slightly diffuse, but, as far as may be observed, on the rest of the body they are normally and regularly imbricate.

Male urogenital structure large, with two fang-like horny claspers curving dorsally, with a long curved fleshy papilla between them curving ventrally. (See A, fig. 3.)

Colour.—Alive: Uniform light salmon-pink, fins light. On preservation the colour has faded to a uniform light buff.

Length.—70 mm.

Locality.—Mouth of the Kasouga River (west of Port Alfred).

Type, a male, in the Albany Museum.

This is the first representative of the genus *Dermatopsis* Ogilby found in our region. Two species, *D. microdon* Ogilby and *D. multiradiatus* McCull. are known from Australia. From these *D. kasougae* is clearly differentiated by the much longer anal fin of many more rays, by the structure of the male genital organ, by the form of the scaling, as well as by several other features. It is actually an open question whether the present species should not be separated by full generic rank from the Australian forms, but it would be advisable to obtain more material before deciding this point.

Family MOBULIDAE.

Despite their relative abundance in tropical waters, these peculiar large rays are rarely available in good condition to the ichthyologist, partly because they are generally of enormous size and difficult to preserve, and partly because of the fear their unusual aspect inspires in ignorant persons. They are probably most inoffensive creatures.

Specimens have only twice been reported from South Africa, and there is no useful description of any complete specimen. In September 1934 the author found a large badly decayed specimen of *Mobula* species on the shore some miles west of East London, but its condition was such as to permit only of a hasty examination of the mouth, and nothing further of value could be ascertained. Recently a complete male specimen of *Mobula diabolus* (Shaw), of comparatively small size, has been obtained, and a description is appended. The peculiar formation of the branchial apparatus is too well known to merit redescription, and this has been omitted.

Mobula diabolus (Shaw).

1925, Barnard, Ann. S.A. Mus. vol. xxi, p. 86, pl. 5, fig. 2 (Figure of a stuffed specimen.) (*M. kuhli.*)

1941, Fowler, U.S. Nat. Mus., Bull. 100, vol. 13, p. 480.

Skin smooth, densely beset with fine pores. Disc 1·85 times as wide as long. Pectorals acute, more or less falcate, anterior margin convex.

The interocular distance is 5·7 in the width of the disc. The eye is 5·7 in the interocular distance. The cephalic horns are of length before the eye 2·1, before the anterior margin of the rostrum 2·5, with the total free lower margin 1·4 in the interocular distance. The greatest depth of the inferior cephalic flap is 2·4 times the eye. The cephalic flap is quite clearly differentiated from the pectorals.

The interbranchial distances are 1st, 1·5; 2nd, 1·6; 3rd, 1·9; 4th, 2·7; and 5th, 4·3 in the interocular distance. The gill slits are 1st, 3·0; 2nd, 2·7; 3rd, 2·5; 4th, 3·3; and 5th, 4·3 in the interocular.

The dorsal is small, inserted about its own length in advance of the hind margin of the disc. Length of base 2·4, height 3·6 in interocular. The tail is whip-like and smooth, without any fold, spine, or post-dorsal prominence, apparently undamaged. Its length is 2·2 in the disc width.

Mouth inferior, front margin of rostrum straight. Width of mouth four times eye diameter, 1·5 in the interocular distance. Dentition feeble, consisting of in each jaw a narrow straight transverse pavement-like band, widest medially, tapering to each end. The band in the upper jaw is slightly shorter than that in the lower, which is exactly half of the interocular. The upper band is about ten times as wide as deep, the lower more slender, almost fifteen times. In each band the teeth form a fairly flat surface, since each tooth is expanded above to an almost plane ovoid top which is extended behind into a ctenoid process, bearing 2–9 blunt points. The average tooth bears 3 points. In the upper jaw is one series bearing 8–9 points each, an abnormality, probably a coalescence. The teeth are

arranged in very oblique rows, with 10 teeth in the longest (medial) rows in the upper jaw, and 11 in the lower. In the depth of the band at the middle are in each jaw 5 teeth, those in the upper jaw being slightly the larger. There are forty-one oblique rows in the upper and fifty-five in the lower jaw. The dentition is obviously in a state of reduction.

The alimentary canal is relatively short. The gullet is about 8 cm. in length passing without expansion into a muscular L-shaped stomach, some 10 cm. in length and about 3 cm. average diameter. The inner surface of the stomach bears 21 relatively large partially furcated transverse rugae which diminish in size towards the pylorus. The latter is pouch-like and muscular, and is unique in possessing no discernible tubular connection between the stomach and the jejunal portion of the canal. The endo-pylorus consists of porous spongy tissue capable of passing matter in a state of fine division, but not even sand. Whether this is a normal condition or an abnormal stenosis may be determined only when further specimens become available for examination. At the exit from the pylorus the canal is abruptly constricted to a diameter of only 5 mm. and continues for 10 cm. to the spiral valve. The latter is fusiform, 13 cm. in length and 3 cm. in diameter at the middle. The spiral valve is relatively complex, comprising 47 complete turns. From the dilated last spiral the rectum is 5 cm. distant. The stomach contained a large amount of sand, while the spiral valve contained only a fine slime consisting of minute organisms, but no sand whatsoever. The liver is large, bilobed. The kidneys are large, much diffused and convoluted.

Colour.—More or less uniform olive-brown above, darker at pectoral apices.

Size.—108 cm. across the disc.

Locality.—Port Alfred, in the estuary, taken on a line. Bait not known, probably fish.

A male specimen, apparently immature, presented by Professor F. W. Armstrong.

This species occurs throughout the tropical Indo-Pacific.

The dentition, the nature of the branchial sieving apparatus, and the character of the alimentary structures all indicate that this fish probably feeds chiefly upon minute or easily crushed substances. The presence of sand in the stomach, and its entire absence from the post-pyloric portion of the intestinal canal, indicate that some food is probably extracted from sand which is then regurgitated. The sieving nature of the pylorus and the much constricted jejunal or duodenal region make it certain that no large particles can be assimilated. The food of this creature must consist of very small organisms, or be of such a nature as to be triturated in the stomach with subsequent regurgitation of any portions which cannot be

reduced to a paste. This would not preclude its feeding upon the flesh of fishes, or of other marine creatures.

I wish to express my gratitude to my wife for the illustrations. Also to the National Research Board for financial assistance which defrayed a part of the costs of the investigation.

ALBANY MUSEUM,
GRAHAMSTOWN,
April 1942.

THE ORIGIN OF THE KENTANI "GAP-DYKES" OF THE TRANSKEI, CAPE PROVINCE.

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The origin of the Kentani gap-dykes is discussed in the light of new chemical data.

Introduction.

The field characters and petrography of the curious gap-dykes of Kentani, Transkei, have long been familiar through the work of Rogers and Schwarz (5, 6), but, though they have been regarded as an acid pre-injection differentiate of the Karroo dolerite magma (du Toit, 3, p. 26), some doubt remains whether the petrographic evidence alone is entirely convincing. In the following note this evidence is reviewed in the light of new chemical data.

Field Characters.

The detailed account of Rogers and Schwarz (*loc. cit.*) renders any but the briefest description of the field characters unnecessary. The two dykes extend east–west across the Kentani district and probably continue farther west into the unsurveyed region W. of the Gcua River. Their visible length in the Kentani division is about 30 miles, and the southerly dyke is the more continuous. The two dykes run parallel for the greater part of their length but branch at a point 8 miles W.N.W. of Kentani. They are doubtless connected underground for they show identical petrographic characteristics.

The course of the dykes is marked by the well-defined trenches or gaps from which they take their name. It is evident that they have resisted erosion less successfully than the surrounding Beaufort beds and dolerite sheets into which they are intruded. They are demonstrably of later age than the Karroo dolerite intrusions, for the N'Hlambe sheet is cut by the dykes near Gobogobo trading station and veined by them on the ridge between the N'Debe and Tutugha valleys. Outcrops of the dyke rock are scanty and take the form of rounded boulder-like joint-blocks. They indicate a width of 300–400 feet for the dykes. In the hand specimen the rock appears to be a coarse micaceous diorite without visible quartz. It is invariably somewhat weathered and of yellowish grey colour with green patches of partly decomposed ferro-magnesian minerals, the proportion of which is variable.

Petrography.

The following notes are intended to supplement the more detailed petrographic descriptions of Rogers, Schwarz, and du Toit (6, pp. 73–75; 4, p. 331) which the author fully confirms.

The Kentani rock is a coarse, basic augite-biotite-diorite in which much of the pyroxene has been converted into brown hornblende. Small and variable proportions of quartz and orthoclase, sometimes micrographically intergrown, are minor constituents and apatite is unusually abundant.

Plagioclase.—Occurs as lath-shaped crystals of normal habit (average size 3×1 mm.) and composition round An_{50}. Zoning is conspicuous and varieties as basic as An_{60} ($\beta = 1{\cdot}562$) were encountered.

Pyroxene.—Only clinopyroxene, generally partly amphibolitised, was observed, the optical properties agreeing well with the normal augite of Karroo dolerites ($\gamma = 1{\cdot}705$; $2V = 45°$; $Z \wedge c = 42°$). The habit is distinctly more stumpy than that of the clinopyroxene in the Karroo dolerite-pegmatites. The colour index is somewhat variable, but the mode of an analysed specimen is given as a fair average:—

Quartz .	2·5	Augite and amphibole .	23·0
Orthoclase .	4·2	Biotite	10·6
Plagioclase .	56·4	Iron ore . . .	2·3
		Apatite . . .	1·0

Petrology and Chemistry.

A lower limit to the age of the Kentani gap-dykes may be fixed with certainty for they are demonstrably later than the Karroo dolerite sheets of the district, but an upper limit is assigned on less satisfactory evidence. The only period of igneous intrustion in the Union after the Karroo episode was that of the Kimberlite pipes and associated melilite-basalts. The gap-dykes are much closer mineralogically to the Karroo dolerites than to the rocks of the Kimberlite suite, and they have therefore been linked with the former magma in previous accounts. Nevertheless their field occurrence and texture differ somewhat from those of the coarser and more dioritic-looking dolerites and are more reminiscent of deep-seated intrusions. Other discrete bodies of acid or sub-acid igneous rock in the neighbourhood show the same characteristics in varying degree and are also of doubtful origin.

Granophyric and coarse dioritic-looking modifications are, indeed, intimately associated with many intrusions of Karroo dolerite, but in such cases it may often be shown conclusively that they are either the products of metasomatism of Karroo siltstone by dolerite or the result of mild crystal fractionation (Walker and Poldervaart, 10). In the latter case the coarse modifications generally occur as contemporaneous schlieren bearing

a strong mineralogical and textural resemblance to the parent dolerite and frequently bordered by types of intermediate character. When the acid modifications are the product of metasomatism they appear to be more or less static, apart from the occurrence of a few rheomorphic veins. No case has yet been found where mobilisation of the metasomatic rocks has taken place on a large scale, and it is to be noted further that they invariably contain relict grains of quartz which have escaped reaction. Mineralogically parts of the gap-dykes are as similar to some of the metasomatic granophyres as to the "pegmatitoides" of the dolerites, but they contain no relict grains or structures.

The mineralogical evidence being not altogether convincing, we are forced to turn to the chemical, and to this end an analysis was made by Mr. F. Herdsman of a typical sample from the centre of the southern dyke 100 yards east of the Kentani-Butterworth road. This analysis is quoted in the table below together with others of a similar magma-type. For better comparison all analyses have been recalculated to 100 per cent. water-free.

	1.	2.	3.	4.	5.	6.	Norm of 1.	
SiO_2	50·56	52·0	52·2	52·2	52·2	57·6	Quartz	5·0
TiO_2	2·06	2·1	2·4	1·3	1·3	0·9	Orthoclase	10·0
Al_2O_3	15·74	16·2	16·5	14·9	15·4	16·9	Albite	22·5
Fe_2O_3	0·95	1·0	3·1	1·1	1·6	3·2	Anorthite	25·9
FeO	10·69	10·8	9·7	9·8	8·7	4·5	Hypersthene {En / Fs	8·5 / 16·2
MnO	0·44	0·4	0·1	0·3	0·1	0·1		
MgO	3·38	3·5	3·5	7·1	7·3	4·2	Magnetite	1·4
CaO	7·56	7·8	8·5	9·9	10·0	6·8	Ilmenite	3·9
Na_2O	2·64	2·7	3·0	2·2	2·4	3·4	Apatite	1·3
K_2O	1·69	1·7	0·9	0·9	0·8	2·1	Calcite	2·8
H_2O+	2·41	..	..	..	..	..	H_2O	2·8
H_2O-	0·34	..	..	..	..	..		
CO_2	1·25	1·3	..	0·1	..	..		100·3
P_2O_5	0·46	0·5	0·1	0·2	0·2	0·3		
	100·17	100·0	100·0	100·0	100·0	100·0		

1. Diorite, southern Kentani gap-dyke 100 yards east of Kentani-Butterworth road. Analyst: W. H. Herdsman.

2. Diorite, southern Kentani gap-dyke 100 yards east of Kentani-Butterworth road, recalculated to 100 per cent. water-free.

3. Quartz-diabase, 700 feet above lower contact, Palisade diabase, N.J. Quoted from Walker (8, Table 3). 100 per cent. water-free.

4. Average of 11 analyses of normal Karroo dolerite. Quoted from Daly and Barth (2, p. 101); Walker and Poldervaart (9, p. 444); and unpublished analyses.

5. Average of 4 analyses of basaltic diabase, Palisade sill, N.J. Quoted from Walker (8, Table 3, and p. 1081).

6. Average world diorite, Daly (1, p. 16).

It will be observed in the above table that the Kentani analysis differs considerably from that of the average world diorite. The chemical evidence seems on the contrary to support the conclusion that the Kentani "gap-dykes" were derived from the Karroo dolerite magma by crystal fractionation, the strongest line of argument being an analogy with the Palisade diabase sill, New Jersey. Analyses 4 and 5 bring out clearly the exceedingly close chemical correspondence between the undifferentiated Karroo dolerite magma and the average chilled Palisade diabase as represented by four very similar analyses of the upper and lower basaltic contacts. Now the Palisade sill shows the effect of crystal fractionation, chiefly by the settling of early olivine and clinopyroxene, very clearly. It is therefore significant that the analysis of the gap-dyke agrees remarkably well with analysis 3 —that of a dolerite from the upper portion of the Palisade sill. If the Palisade dolerite were produced by crystal fractionation, so might the Kentani rock have been, in some deep-seated magma chamber where plutonic conditions prevailed. This would account for the habit and texture of the rock. It is quite conceivable that such differentiated magma could have been drawn off from the upper part of the chamber and injected in dyke form. Such an hypothesis is admittedly speculative, but it seems competent to account for the origin of the gap-dykes and would confirm the observations of du Toit (3A, p. 204) on the plutonites of the highly differentiated Lebombo region.

The gap-dykes cannot be regarded as the product of metasomatism. Not only are relict minerals and structures completely absent, but the analysis shows no corundum in the norm. All the available analyses of metasomatic granophyres associated in the Karroo dolerites (Walker and Poldervaart, 10, pp. 285–307) contain significant proportions of this constituent in the norm, and the same is true of the roof-zone of the Ingeli mass for which Scholtz (7, p. 96) does not exclude a sedimentary origin. There is admittedly enough Al_2O_3 in the Kentani analysis to convert all the residual CaO of the norm to anorthite, leaving none for diopside, but the high CO_2 content of the rock must be reckoned with in this connection. This takes up a considerable proportion of CaO to form normative calcite. A similar state of affairs is found in the analysis of the upper contact basalt of the Hangnest dolerite sill (Walker and Poldervaart, 9, pp. 444–448). In both cases, if the CO_2 (which chiefly represents decomposed ferro-magnesian metasilicates in the mode) is ignored and the CaO thus made available to form normative diopside, the total normative pyroxenes will then agree respectively in composition with those of normal Karroo dolerites and of their fractionated differentiates, *i.e.* dolerite-pegmatites.

General Conclusions.

An analysis of one of the Kentani gap-dykes matches closely with that of a coarse dolerite from the upper part of the Palisade diabase sill. Since the average chilled Palisade magma agrees almost exactly in chemical composition with undifferentiated Karroo dolerite, it can be argued that the Kentani rock was produced from the Karroo dolerite magma in some deep-seated chamber by the same processes operating in the American sill, viz. settling of early olivine and clinopyroxene crystals probably accompanied by a slight upward infiltration of acid material. This is in accordance with the conclusions reached by earlier workers on petrographical grounds.

Acknowledgments.

Grateful acknowledgment is expressed to Drs. A. W. Rogers and S. H. Haughton, through whose good offices the Geological Survey slides were made available to the author, and to the National Research Council for a grant which defrayed the cost of transport and of the chemical analysis.

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THE PETROLOGY OF THE ELEPHANT'S HEAD DIKE AND THE NEW AMALFI SHEET (MATATIELE).

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(With Plates I and II and ten Text-figures.)

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ABSTRACT.

Two allied intrusions of Karroo magma are described in detail. The one intrusion is a multiple Dike of exceptional form, uneven top, and great length. It served as the feeder of the second intrusion, a thick transgressive Sheet. In the dike, a first intrusion of tholeiite magma was followed by the injection of a large volume of olivine-dolerite magma. The sheet only contains the cooled representatives of the olivine-dolerite magma. A considerable degree of magmatic differentiation in the latter magma has led to the production of a great variety of rock types in both sheet and dike. Both magmas were very active in their behaviour towards the associated sediments. The tholeiite magma mobilised and reacted with the Molteno sediments of the dike-walls. In the sheet, a block of Burghersdorp sandstone was metasomatised by emanations, derived from the olivine-dolerite magma.

CONTENTS.

I. Introduction.

The New Amalfi Sheet and the Cape portion of the Elephant's Head Dike were mapped and described by du Toit (1929, pp. 24–25), who also gave a brief account of some of the rock-types encountered. The maps contained in this study are largely based on du Toit's work, the excellence of which did not allow for much improvement. Mr. G. M. Stockley traced the dike for a further 37 miles in Basutoland and kindly provided the author with information concerning the Basutoland portion of the dike.

The present study is confined to the Cape Province, as conditions did not allow for extension of the work into Basutoland.

II. Acknowledgments.

The writer wishes to express his gratitude to Professor F. Walker, of the University of Cape Town, for his guidance and help in the research; to Dr. A. L. du Toit for his interest and useful advice; and to Mr. J. A. Purchase of Ashton for his great hospitality. The cost of twelve chemical analyses was met by a liberal grant of the National Research Board, which is here gratefully acknowledged. The author is also indebted to Professor F. Walker and to Professor D. L. Scholtz, of Stellenbosch University, for allowing him to use several of their unpublished analyses for the diagrams.

III. Field Characters.

The location and extent of the occurrences can be read from the Survey map, Cape Sheet No. 35, Matatiele.

The New Amalfi Sheet transgresses towards the north-west. It has invaded the Burghersdorp beds, which, like all other sedimentary formations in the area, dip at 2°–5° towards the Drakensberg range, and has a rather irregular outcrop. Surrounding it are various cross-cutting side-intrusions arising from the main body and allied to it petrologically. The rock of the sheet is a coarse-grained, bluish-black dolerite, frequently enveloped in a thick, reddish-brown, weathering crust. At higher horizons the rocks become progressively paler in colour.

Within the New Amalfi exposure numerous sedimentary xenoliths were encountered. The xenoliths consist of argillaceous material, baked to a hard, black hornstone. No reaction phenomena with dolerite were observed, but examples of rheomorphic veining of dolerite by mobilised sediment proved exceedingly common.

All along the western boundary of the sheet there occurs a well-defined, 60–80 feet broad band of pale-coloured granophyric rocks. The dolerites, both above and below the zone, show sharp and chilled margins against

the granophyre. Along the lower border the chilled phase may, however, be absent over long stretches of the contact, when the granophyre directly overlies the coarse-grained rocks of the sheet. A few veins of granophyre, up to 4 inches wide, extend from the main zone and are intrusive in the dolerite. The granophyric rocks show great differences in grain size. Generally a considerable increase in grain is noted near the vertical joint-planes which dissect the exposures. Along such planes the rock is extremely coarse-grained, and may show rude grid-iron structures, due to the interlocking of ragged prisms of greenish-black ferromagnesian minerals, several inches in length.

Several rounded sandstone xenoliths occur in the granophyric zone. The material closely resembles the fine-grained Burghersdorp sandstone, and the xenoliths may be in all stages of digestion. Commonly a core of yellow sandstone is surrounded by one or more transitional zones, which show sharp margins against each other and against the normal granophyre.

The Elephant's Head Dike emerges from the sheet on the farm Hanover, near the entrance of the Umzimvubu River into the New Amalfi intrusion. On the boundary line of Mooi Plaats and Mzongwani's Location the dike seemingly merges into a thin sill, only to reappear farther west. Thence it continues to Calamity Hill, where it encounters a long spur of Molteno sediment, projecting from the Drakensberg range. The dike disappears into this spur, but outcrops again farther west along the plateau at several quite unexpected places, between which the strata run unbroken and undisturbed.

The best illustration of this curious behaviour is afforded by the imposing dolerite block of the Elephant's Head peak, which forms part of the high spur of Molteno sediment. The peak stands detached from the main plateau on three sides and exposures are excellent. Towards the north-west the dike dips at 10° under the horizontal Molteno beds. Towards the south-east, however, it descends at a high angle, and thus no trace of the dike can be found at the other side of the deep gorge, which here separates the peak from the main plateau, but the Molteno beds show marked columnar jointing at the bottom of the gorge, indicative of the dike's continuation at yet lower levels. The dike-walls are perfectly vertical, and the incision of deep clefts into its frontal face has given the peak a close resemblance to an elephant's head.

With such an undulating crest the dike climbs up the Drakensberg, to enter Basutoland at Montai. Thus, on the Cape side the 250–400 yards wide intrusion ascends, within a distance of some eighteen miles, roughly 3000 feet. In Basutoland the intrusion runs through even more mountainous country, but here its outcrop is apparently continuous. From Montai it follows a general N.W.W. direction, descends into the Orange

River valley, crossing the river five times, thence crossing the Sinqungane River six miles above its confluence with the Orange River, to disappear finally in the great mountainous tract of Mount Robinson, through which it was not followed.

The igneous contents of the dike consist of tholeiites, picrites, and olivine-dolerites. Tholeiites are found along the margins of the intrusion

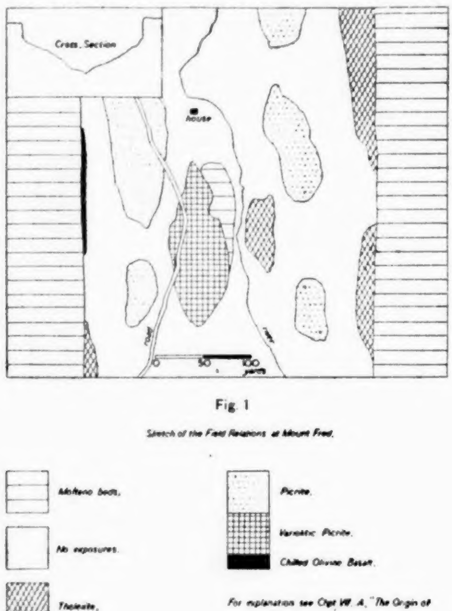
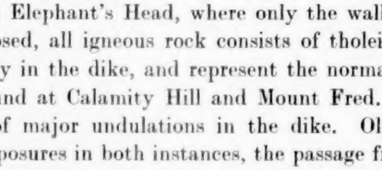


Fig. 1

Sketch of the Field Relations at Mount Fred.



For explanation see Chpt VII. A, "The Origin of the Variolitic Picrite".

and invariably show sharp contacts against the picrites and olivine-dolerites. At Elephant's Head, where only the walls and the roof of the dike are exposed, all igneous rock consists of tholeiite. Olivine-dolerites occur centrally in the dike, and represent the normal dike-rock. Picrites were only found at Calamity Hill and Mount Fred. Here they occur at the bottom of major undulations in the dike. Olivine-dolerite overlies the picrite exposures in both instances, the passage from picrite to olivine-dolerite being gradual. The field relations in the river valley at Mount Fred are somewhat unusual (fig. 1), and a variolitic variety of picrite occurs here, forming an isolated exposure near the bottom of the valley.

Lateral intrusion and stoping resulted in the inclusion of blocks of sediment within the dike. On the north-west slope of the poort on

Mahainkwe, one such inclusion is seen, crossing the dike as a bar of Molteno sandstone, with dolerite exposed above and below the sediment. At Elephant's Head and Calamity Hill several instances of magmatic attack on the Molteno sediments of the dike's walls and roof were noted. Even the coarse Molteno grits did not escape conversion, the ultimate product being a grey granophyric rock in which rounded lumps of unaltered quartzite are embedded.

IV. Petrography.

In this study refractive indices were determined by immersion methods in sodium light. Axial angles and extinction angles were measured on a 4-ring Universal Stage. The modal compositions of the rocks were assessed with a Leitz Integrating Stage, the traverses varying from 300–600 mm. Plagioclase was determined on the average β only. Olivine was determined on 2V and γ according to the diagram of Deer and Wager (1939 *a*, p. 21). The orthopyroxenes were measured for 2V and γ. The compositions of the magnesian orthopyroxenes were derived from the curves of Hess and Phillips (1940, p. 280); those of more iron-rich orthopyroxenes from Henry's diagram (1935, p. 223). For the clinopyroxenes 2V, $\gamma \wedge c$ and γ^1 were measured. γ was calculated by adding 0·004 to the observed value γ^1 (Tomita, 1934, p. 47).

A. *Tholeiites.*

The tholeiites show chemical and petrographical characters which class them in a group of their own. They occur only in the dike, and are considered to represent the first magma to intrude the dike-plane. The rocks consist of plagioclase, clinopyroxene, and mesostasis, while iron ore and olivine occur in minor amounts. Plagioclase (An. 61) builds broad laths, showing slight zoning. Clinopyroxene is hypidiomorphic and brown in colour. Zoning is negligible; the optical properties are 2V : 41°, $\gamma \wedge c$: 45°, γ : 1·725. Olivine occurs as large crystals, invariably pseudomorphosed in yellow serpentine. Iron ore builds skeletal crystals, moulded on plagioclase or pyroxene. The interstitial mesostasis contains skeletal plagioclase laths, elongated, prismatic clinopyroxene, quartz and abundant iron ore. The chilled modifications show phenocrysts of plagioclase, clinopyroxene, and rare, altered olivine. The ground-mass is a fine-grained copy of the normal tholeiite, except that olivine is absent.

B. *Picrites.*

The normal picrites of Mount Fred and Calamity Hill are petrographically very similar. They resemble the basal phases of the Insizwa lopolith, described in detail by Scholtz (1936, pp. 102–117).

Olivine occurs as well-developed crystals, decreasing gradually in amount from 61–22 per cent. Crystals are non-zonal, though different grains may have different compositions, ranging from Fa. 17–23. Plagioclase is poikilitic in habit in the picrites richer in olivine, where it forms stout crystals (An. 70), showing but little zoning. With decreasing olivine percentage, a second generation of slender, zonal laths (An. 66) becomes increasingly more abundant. As the first generation is substituted by the second, the larger crystals assume a more complex character as regards zoning and twinning. Pyroxene is poikilitic in habit, but at 22 per cent. olivine the mineral changes its habit and becomes subophitic. Both ortho- and clinopyroxene occur in the picrites. Orthopyroxene (Of. 15–18) constitutes 15–30 per cent. of the total pyroxene. The optical properties of the clinopyroxene are $2V: 49°–46°$, $\gamma \wedge c: 38°–36°$, $\gamma: 1{\cdot}713–1{\cdot}716$. Iron ore occurs in the most basic rocks as small, chromiferous octahedra, enclosed alike in olivine, plagioclase, or pyroxene. In picrites with less olivine, the ore is of late crystallisation and forms large skeletal masses, in which chromium is absent. The usual deep reddish-brown biotite forms a constant accessory, and is regarded a reaction product of chromiferous ore. A few yellow patches of sulphidic ore occur scattered through the rocks.

The variolitic picrite contains phenocrysts of olivine (Fa. 15), set in a fine-grained groundmass, in which olivine also occurs in a second generation (Fa. 17). The groundmass consists of slender laths of feldspar (An. 70) and subophitic, elongated clinopyroxene ($\gamma: 1{\cdot}713$), together with small octahedra of black ore. Bundles of feldspar and pyroxene have a fan-shaped arrangement, reproducing the structure of the variolitic basalts.

In one specimen a small xenolith of black, compact hornstone was found. The material of the xenolith is not resolved by the microscope, but marginally two narrow, monomineralic zones occur. The inner one consists of a single layer of iron ore granules. The second zone shows numerous small olivine crystals of composition Fa. 17, closely packed together.

C. *Olivine-Dolerites.*

These rocks range in grain size from medium to coarse, while the texture is subophitic to ophitic. In the dike the dolerites are generally finer grained than in the sheet, though an increase in grain size is noted in the dike-rock at Hanover. Again, the dolerites of the dike contain generally less olivine than those of the lower parts of the sheet, but here too differences are abridged in the Hanover section. Olivine-dolerites occur in the lower and central portions of the sheet, becoming progressively poorer in olivine upwards.

Olivine occurs in a wide range of compositions (Fa. 28–47). In the dike it forms groups of small fayalitic crystals, together with a few larger grains. In the sheet crystals are well-developed and large. Although individual rocks invariably show a range in olivine compositions, this tends to become more fayalitic upwards in the sheet. Thus in the centre of the sheet the normal olivine is Fa. 46, whereas in the lower parts Fa. 30 is most common.

Plagioclase (An. 66) builds zonal laths. In the dike the laths are slender, but the sheet contains broad crystals of plagioclase. Little variation in the average composition was observed.

Clinopyroxene is subophitic, and pale greenish brown in colour. Crystals are strongly zonal, the range in optical properties being 2V : 49°–31°, $\gamma \wedge c$: 38°–33°, γ : 1·713–1·725. The grains often show twinning of the butterfly type. Orthopyroxene has a considerable range in composition in individual rocks. It commonly occurs as subophitic crystals showing a graphic intergrowth of exsolved $CaSiO_3$ on a minute scale. The majority of the grains are of later formation than clinopyroxene (Of. 26–34), but a few are of earlier crystallisation (Of. 20). Rarely a third generation occurs as ophitic plates of composition Of. 42. These do not show the intergrowth and are pleochroic in tints of green and reddish brown. In the dolerites of the centre of the sheet rare, colourless, columnar crystals of early pigeonite were observed, forming cores to mantles of ortho- or clinopyroxene. It has 2V : 13°, $\gamma \wedge c$: 34°, and γ : 1·700. Black ore forms skeletal masses of late crystallisation. Golden-brown biotite (γ : 1·646) and apatite are ubiquitous, and likewise of late crystallisation. Interstitial micropegmatite occurs in varying but always small amounts.

An interesting rock occurs as a small, pipe-like intrusion in Molteno sandstone at the foot of the Elephant's Head peak. The rock shows alliances to the P.K. type of Karroo dolerite (Walker and Poldervaart, 1941 *a*, pp. 137–140), but is unusually rich in olivine. This mineral occurs as a few large crystals (Fa. 15) and abundant small grains (Fa. 23). Plagioclase (An. 70) forms narrow, zonal laths. Pyroxene (aver. 2V : 47°) is of the monoclinic variety only and builds zonal, ophitic plates. Octahedral iron ore and reddish-brown biotite are accessories. The intrusion is regarded as an offshoot of the dike, and indicates the presence of olivine-dolerite at Elephant's Head, though the rock is concealed by the tholeiitic mantle.

D. *Iron-rich Dolerites.*

From the map of the New Amalfi intrusion the relative distribution of the rock-types can be observed. The iron-rich dolerites form a narrow

zone in between the olivine-dolerites and the band of metasomatic granophyre. The boundary line with olivine-dolerite is arbitrarily drawn, and is not intended to represent a sharply defined contact. The division between olivine-dolerite and iron-rich dolerite was drawn at the point of failure of olivine to crystallise. Iron-rich dolerites at higher horizons again show olivine, though then markedly more fayalitic.

The group of the iron-rich dolerites shows a rapid and progressive change in mineralogical characters. The rocks change upwards from quartz-dolerites, rich in iron, to fayalite-quartz dolerites and thence to fayalite-hedenbergite granophyres. The ferromagnesians become poorer in magnesium silicate and richer in iron silicate, while the felsic minerals increase in amount and become progressively richer in soda and potash. The hydrous silicates likewise increase in proportion as higher horizons in the sheet are reached. In the fayalite-hedenbergite granophyre large masses of olive-brown serpentine occur. Some of this is demonstrably derived from fayalite or pyroxene, but most seems to have formed during the hydrothermal stages of crystallisation.

Olivine is absent in the lowest members of the iron-rich group, to reappear again at slightly higher horizons as Fa. 80. Becoming progressively more fayalitic it persists into the highest rocks, where pure fayalite is recorded. The mineral occurs as small, rounded, yellow-brown grains, associated with iron ore and micropegmatite. Plagioclase occurs in the lowest members as broad, zonal laths (An. 60), but becomes progressively richer in albite at higher horizons, to reach An. 31 in the fayalite-hedenbergite granophyre.

Clinopyroxene is subophitic. In the lower members of the group the mineral shows the platy alteration to biotite and the fine striations, so commonly observed in teschenitic rocks. The clinopyroxenes are only slightly zonal, but generally each rock contains two generations of the mineral, which testifies to the iron enrichment of the pyroxene crystallisation. Thus the following sequence was established, in ascending order:—

Pale greenish-brown augite (2V : 40°, $\gamma \wedge c$: 44°, γ : 1·721).
Pale purple-brown ferroaugite (2V : 50°, $\gamma \wedge c$: 45°, γ : 1·734).
Pale green ferroaugite (2V : 52°, $\gamma \wedge c$: 43°, γ : 1·740).
Green hedenbergite (2V : 56°, $\gamma \wedge c$: 45°, γ : 1·758).

The highest member of the group contains purple and green hedenbergite, without there being any appreciable difference in the optical properties. The purple colour is probably due to the presence of some TiO_2.

Orthopyroxene occurs in the lower members of the group as small, stumpy crystals, moulded on clinopyroxene. The range in composition

observed is Of. 67–79. The mineral is absent in the fayalite-hedenbergite granophyre. Among the accessories, dark-brown biotite (γ : 1·673) only occurs in the lower dolerites, being substituted by brown hornblende (γ : 1·693) in slightly higher rocks, and by greenish-blue hastingsite (γ : 1·709) in the highest members of the group. Iron ore occurs as large skeletal masses and becomes progressively more titaniferous upwards.

E. *Pigeonite-Dolerites.*

Near the margins of the New Amalfi sheet, dolerites of somewhat modified character occur. Similar rocks are found above the band of metasomatic granophyre, and in many of the side intrusions. The rocks are generally coarse-grained; the texture is subophitic to ophitic. Olivine occurs in small amounts and is invariably altered to bluish-green, pleochroic bowlingite. Plagioclase (An. 69) builds broad, zonal laths. Pyroxene is of the monoclinic variety only, and includes early pigeonite (2V : 5°–10°, $\gamma \wedge c$: 38°–36°, γ : 1·702–1·705), augite (2V : 46°–44°, $\gamma \wedge c$: 38°–36°, γ : 1·716–1·718), and late pigeonite (2V : 13°–6°, $\gamma \wedge c$: 30°–34°, γ : 1·733–1·735). Early pigeonite forms colourless, columnar cores to mantles of augite, while late pigeonite occurs as brown fringes around augite crystals. Skeletal iron ore occurs in addition. A dark mesostasis frequently takes the place of micropegmatite.

The thin sheet at Mooi Plaats contains a dolerite of identical characters. du Toit, in discussing the relations of the dike and this sheet, remarks: "Not many miles up the Big Umzimvubu, at Hanover, a slightly inclined sill, when followed westwards, turns upwards, becomes vertical, and thus acquires the habit of a dike" (1929, p. 24). The rock of the sheet indeed continues a certain distance along the course of the dike, when it gives way to the typical olivine-dolerite. The Mooi Plaats sheet forms locally the highest exposures, while olivine-dolerite outcrops at much lower levels. Thus it is preferred here to consider the sheet superimposed on the roofed dike. The magma of the former apparently followed the latter's course for some distance. Unfortunately exposures do not allow for detailed studies, but at one place on the Hanover side a thin strip of sandstone was found, parting the two intrusions. Hence the dike is thought to continue uninterruptedly from Calamity Hill to Taylorville, underneath the Mooi Plaats sheet, and thence into the New Amalfi intrusion.

F. *Chilled Olivine-Basalts.*

Olivine-basalts are found in the dike, as along its southern contact at Calamity Hill. In the New Amalfi sheet they border the eastern contact. In addition, chilled basalts occur along the eastern margin of the band

of metasomatic granophyre. A few thin dikes within the granophyre band, likewise contain basalts of this type. The dikes peter out rapidly and their contents are always intensely altered.

The basalts contain phenocrysts of olivine (Fa. 15), plagioclase (An. 72), and clinopyroxene ($2V : 51°$, $\gamma \wedge c : 44°$, $\gamma : 1{\cdot}704$). The volume percentages are respectively 3·1, 9·2, and 1·0. The groundmass consists of plagioclase, pyroxene, olivine, and abundant iron ore dust.

V. Mineralogy.

Plagioclase shows little change in composition in the more basic rocks, varying from An. 70 in the picrites to An. 66 in the olivine-dolerites. In the narrow zone of the iron-rich dolerites, however, there is a rapid increase in the albite content of the series, reaching An. 31 in the fayalite-hedenbergite granophyre. The plagioclase crystals are lath-shaped in most of the rocks, but their dimensions are subject to pronounced variations. In the most basic picrites the feldspar is poikilitic in habit. In a former paper (Walker and Poldervaart, 1942 *a*, pp. 62–63) it was pointed out that: "Those sills in which early olivine has settled *in situ*, show a marked increase in size, and a change in the habit of the plagioclase in the portions, which have been enriched in the orthosilicate. The feldspar in such cases becomes poikilitic and is often slightly more calcic than that of the associated dolerites. In picrite sills, where differentiation has not taken place *in situ*, the habit of the plagioclase remains lath-shaped as in the associated dolerites." In the dike both picrite-types are met with, the poikilitic types being richer in olivine and underlying the second type.

Olivine changes progressively in composition, from Fa. 15 in the variolitic picrite to Fa. 47 in the olivine-dolerite underlying the iron-rich zone. After a short discontinuity in its crystallisation, the mineral reappears as Fa. 80 and continues to crystallise, reaching Fa. 100 in the rock richest in iron. Such observations are analogous to the theoretical deductions of Bowen and Schairer (1935). Under conditions of strong fractionation the system MgO–FeO–SiO_2 first precipitates olivine of changing composition. Next the liquids pass into the pyroxene field, and pyroxene alone precipitates. Finally there is a return to the boundary between the two fields, when olivine and pyroxene crystallise simultaneously. In the latter case the olivine is more fayalitic than before its disappearance.

The olivine crystals are non-zonal. Rather, different rocks are marked by olivines of a different range of compositions. In the variolitic picrite a range Fa. 15–17 was recorded; in the normal picrites Fa. 17–23; and in the olivine-dolerites ranges varying within the limits of Fa. 28–47. The absence of zoning suggests that olivine crystals react more readily

with the magma than, for instance, crystals of plagioclase or pyroxene. The preservation of crystals, richer in Mg_2SiO_4, is apparently due to the withdrawal of such crystals from further interaction with the magma. This is achieved by (i) rapid cooling, (ii) sinking of crystals to lower levels in the magma chamber, and (iii) the development of thin protective films on the surface of crystals.

The orthopyroxenes, likewise, show a progressive change in composition, varying from Of. 15 in the picrites to Of. 79 in the fayalite-quartz dolerite. The crystallisation period of the orthopyroxenes overlapses that of the clinopyroxenes. In the picrites, orthopyroxene (Of. 15–18) is of earlier formation than clinopyroxene. The orthopyroxene of the olivine-dolerites (Of. 26–34) is essentially contemporaneous with clinopyroxene. In the iron-rich dolerites, orthopyroxene (Of. 80–100) is of late formation. The mineral follows the trend of olivine, both in composition and crystallisation period. Magnesian and medium olivine crystallised prior to bronzite and hypersthene. More fayalitic olivines are contemporaneous with the ferro-hypersthenes. Pure ortho-ferrosilite did not form, but quartz and fayalite crystallised instead.

In crystals of composition Of. 20–35 a graphic intergrowth is observed. Similar observations were made by many other authors (Walker, 1940, p. 1073; Hess and Phillips, 1940, pp. 282–284; Walker and Poldervaart, 1941 *b*, p. 435). Its extremely fine grain often hinders accurate determination of the optical constants. The author could only determine γ in these orthopyroxenes, but no uniform extinction could be obtained in any position on the universal stage. The relations between early pigeonite and orthopyroxene in the New Amalfi sheet are summarised here. The author's conclusions closely agree with those expressed by Hess (1941, pp. 580–581).

1. Pigeonite with the optic axial plane $\perp$ (010), and orthopyroxene with a graphic intergrowth bear a complementary relationship to one another.
2. Early pigeonite crystallised at high temperature, prior to orthopyroxene (Of. 20–35), showing the intergrowth.
3. On rapid cooling, early pigeonite is preserved in a metastable condition. On slow cooling early pigeonite inverts to orthopyroxene with a graphic intergrowth.
4. The intergrowth originates in the excess of lime contained in the molecule. Normally the phenomenon is one of exsolution, and the intergrowth consists of some form of exsolved calcium metasilicate. In other cases lime is not exsolved, but the intermolecular strain produced causes a fine lamellar twinning in the crystals (Scholtz, 1936, pp. 111–115).

5. With high concentrations of volatiles (mainly water), early pigeonite becomes stable at all temperatures, and may thus also occur in slowly cooled, coarse-grained rocks (*cf.* Walker, 1940, p. 1090).

Diagrammatically the sequence suggested is:—

Olivine (Fa. 17) ⟶ *Early Pigeonite* (Wo. 14, En. 59, Fs. 17)

↓

Orthopyroxene with intergrowth (Of. 22).

The relations between late pigeonite (Wo. 9, En. 41, Fs. 50) and orthopyroxene are more complex and have as yet not been satisfactorily solved. The problem clearly requires further study.

The compositional trend of the remaining clinopyroxenes shows a similar progressive enrichment in iron. The compositions were obtained by plotting the values for γ and 2V on the diagrams of Deer and Wager (1938, pp. 20–21). Representative data of the Elephant's Head and New Amalfi pyroxenes are here tabulated.

TABLE I.

No.	2V.	$\gamma \wedge c$.	γ.	Wo.	En.	Fs.
1	51°	44°	1·704	36	47	17
2	49	38	1·713	32	44	24
3	46	38	1·716	28	44	28
4	44	36	1·718	27	44	29
5	40	44	1·721	22	44	34
6	34	35	1·723	20	44	36
7	31	33	1·725	18	44	38
8	41	45	1·725	22	42	36
9	50	45	1·734	29	32	39
10	52	43	1·740	32	25	43
11	56	45	1·758	38	9	53

The compositions were plotted on a triangular Wo.–En.–Fs. diagram, together with the "pyroxene course of crystallisation in normal mafic magmas" of Hess (1941, p. 585) (fig. 2). It is emphasised that the information yielded is purely of an approximate character, as only chemical analysis can ascertain the composition of the clinopyroxenes with accuracy.

The deep depression in the crystallisation trend illustrates the tendency for the development of pigeonitic types, during the middle stages of crystallisation. Indeed, the author does not exclude the formation of true pigeonites (2V < 30°) during this stage, though stipulating that such pigeonites would have the optic plane ‖ to (010). Thus a genetic division

is drawn between pigeonite with the optic plane ⊥ (010), bearing a reaction relationship to olivine and orthopyroxene, and pigeonite with the plane ∥ (010), concordant with the clinopyroxene course of crystallisation. The first part of the crystallisation trend (2V : 49°–31°) is typical for the clinopyroxene sequence in normal Karroo dolerites. The change in direction

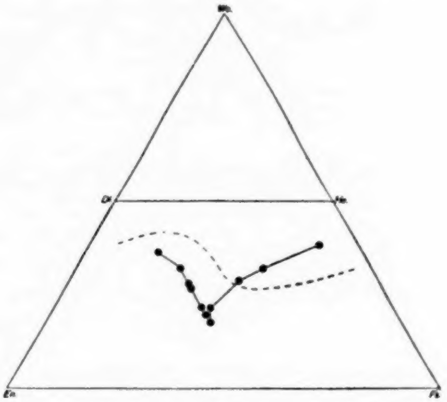


Fig. 2

Clinopyroxene Course of Crystallisation.

Optically determined clinopyroxenes.

Hess' Pyroxene Course of Crystallisation.

of the crystallisation coincides with the cessation of early crystallising olivine, and of pigeonite.

The data for the four chief groups of rock-forming minerals show a progressive enrichment in soda in the plagioclase series, and an equally progressive enrichment in ferrous iron in the olivine, orthopyroxene, and clinopyroxene series. The latter trend appears to be even more marked than the soda enrichment.

Chromiferous iron ore crystallised at a very early stage, while later-formed ore shows a progressive enrichment in titania. Hydrous silicates, quartz, and anorthoclase increase in amounts in the higher, iron-rich dolerites.

VI. Chemistry.

Seven representative specimens of picrites and dolerites were chemically analysed by Mr. F. Herdsman. It is noted that the picrite analyses did not return Cr_2O_3, although qualitative examination gave a positive test for chromium.

A. *Magmatic Variation.*

In fig. 3 the oxides of analyses 11, 39, 58, 25, 20, 52, and 18 were plotted against the ratio $\frac{FeO + Fe_2O_3}{MgO + FeO + Fe_2O_3} \times 100$ (Deer and Wager, 1939 *b*, p. 300). This method of representing analyses is very suitable for basic and intermediate rocks, though its uses for more extreme differentiates are naturally restricted. The diagram brings out the points registered in the mineralogical study of the rocks. The formation of the picrites is reflected by sharp declines in the curves for MgO, FeO, and Fe_2O_3, accompanied by complementary increases in the proportions of all other oxides. The variation shown is clearly due to the precipitation of chromiferous magnetite and magnesian olivine in excess of the stoichiometric proportion. The incoming of basic plagioclase during the next stage produced a sharp decline in the CaO curve, while MgO decreases more gently. FeO and Fe_2O_3 now show an increase, as olivine has ceased to separate in excess of the stoichiometric proportion. The following stage reflects the simultaneous crystallisation of plagioclase and pyroxene, becoming progressively enriched in respectively soda and iron. Hence a decline is shown in the curves for CaO, MgO, and Al_2O_3, while all other oxides increase in proportion.

The closing stages of magmatic variation are more complex. The later rest-magmas migrated upwards in the sheet and attacked the crystal framework through which they passed. Moreover, the extreme differentiates occur just below the band of granophyric rocks, originating in the metasomatic conversion of Burghersdorp sandstone. The process of metasomatism involved the selective migration of certain oxides across the contact in both directions. Hence the igneous rocks below the granophyric zone both lost and gained in certain constituents. These gains and losses are, however, not clearly demonstrated by the analyses.

The mineralogy of the extreme differentiates shows them to be continuations of the crystallisation trend of the olivine-dolerite series. Moreover, the magmatic variation shown closely agrees with that of similar igneous bodies elsewhere (*cf.* Deer and Wager, 1939 *b*). In a qualitative manner the diagram, therefore, reflects the trend of magmatic variation. The proportions of FeO, Fe_2O_3, and TiO_2 reach well-defined maxima in the fayalite-quartz dolerite, but the fayalite-hedenbergite granophyre shows that enrichment in Na_2O, K_2O, and SiO_2 was more pronounced during the final stages of crystallisation. Practically this means that "the competition—between the two principal solid solution series, plagioclase feldspars and iron-bearing metasilicates (*e.g.* pyroxenes)" (Fenner

1931, p. 549)—was first won by the pyroxenes, but ultimately by the plagioclases.

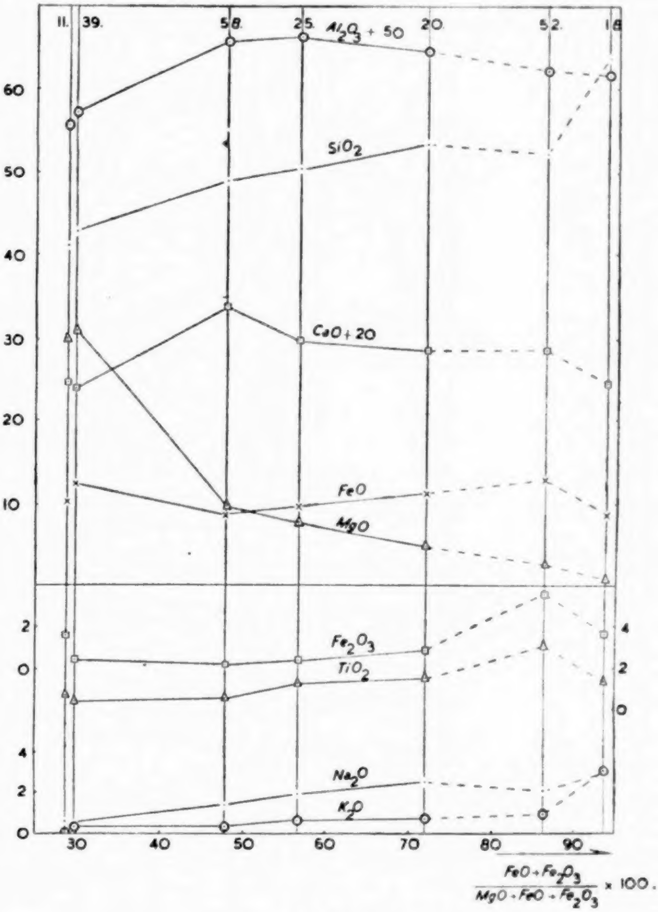


Fig. 3

Variation of the rocks derived from the Olivine-dolerite Magma.

In figs. 4 and 5 the trend of differentiation is further illustrated by plotting the analyses on a triangular basis. The three corners are respectively MgO, the significant constituent of the more refractory minerals;

FeO, the significant constituent of the medium refractory minerals; and ($Na_2O + K_2O$), the significant constituents of the less refractory minerals. In fig. 4 the trend of differentiation of the Elephant's Head and New Amalfi intrusions is compared with the strongly fractionated Skaergaard

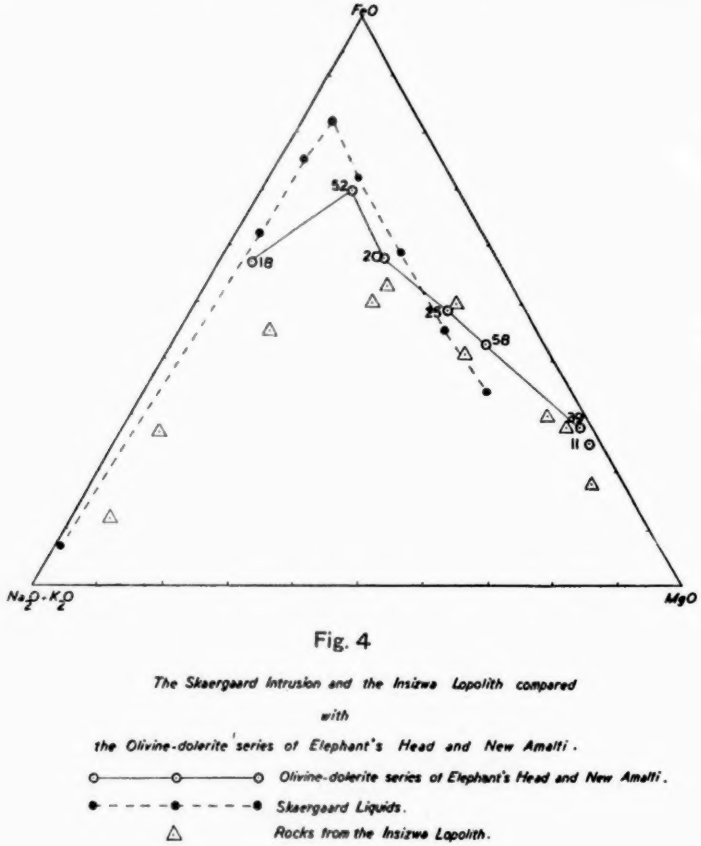


Fig. 4

The Skaergaard Intrusion and the Insizwa Lopolith compared with the Olivine-dolerite series of Elephant's Head and New Amalfi.

intrusion (Deer and Wager, 1939 *b*), and that of the Insizwa lopolith (Scholtz, 1936), which only shows medium fractionation. It appears that the iron enrichment of the middle stages of crystallisation depends primarily on the degree of fractionation of the magma. In fig. 5 all available Karroo analyses are plotted. Iron enrichment is apparently inherent in the crystallisation of the Karroo magma.

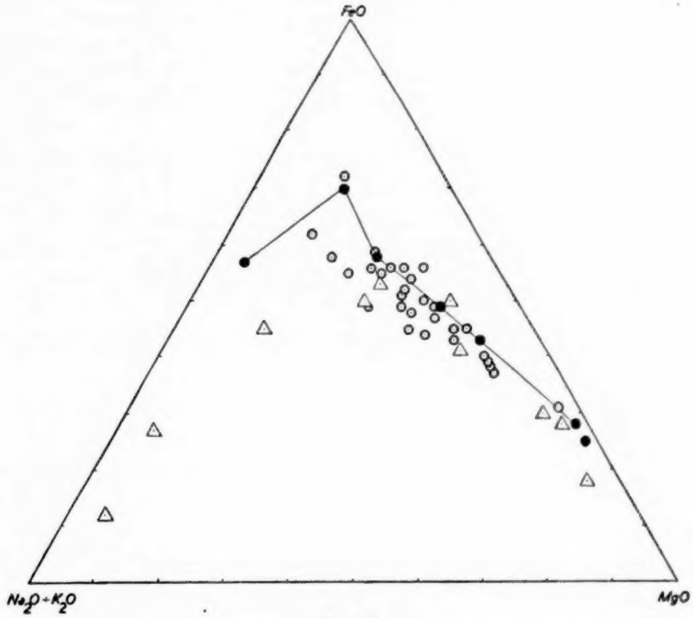


Fig. 5

The Olivine-dolerite series of Elephant's Head and New Amalfi compared with all other analyses of Karroo Dolerites.

● *The Olivine-dolerite series.*
△ *Analyses of Insizwa rocks.*
⊙ *Other Karroo analyses.*

B. *The Original Olivine-Dolerite Magma.*

As the chilled basalt was not analysed, attempts were made to arrive at an approximation of the composition of the original magma. The analysis of the variolitic picrite was recalculated as water-free, adjusting Fe_2O_3 to 0·5 per cent. (11 *a*). Next 60 per cent. olivine Fa. 20 was subtracted, and the result again recalculated to 100 per cent. (A). The composition of a magma with 48·0 per cent. SiO_2 was also deduced from the variation diagram (B). Finally, the average of Frankel's four analyses of younger Karroo intrusions (Frankel, 1942, p. 18) was recalculated as water-free and minus Cr_2O_3 (C).

TABLE II.

	SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MgO.	CaO.	Na_2O.	K_2O.	TiO_2.	P_2O_5.	MnO.	Total.
II *a* .	43·3	6·1	0·5	12·0	31·6	4·8	0·6	0·1	0·8	..	0·2	100·0
A .	48·0	15·2	1·2	9·0	10·3	12·0	1·5	0·2	2·0	..	0·6	100·0
B .	48·0	14·6	0·5	9·5	12·5	12·3	1·2	0·4	0·6	0·2	0·2	100·0
C .	49·1	13·6	1·1	9·6	13·0	9·8	2·0	0·5	0·9	0·2	0·2	100·0

Considering the limitations of such calculations, the agreement between A, B, and C is striking. The most significant differences are in the proportions of CaO, Al_2O_3, and Na_2O. This is reflected in the fact, that the dolerites of the Matatiele intrusions are considerably richer in plagioclase than those of Frankel's younger dikes.

C. *The Tholeiite Magma.*

In fig. 6 the Elephant's Head tholeiite is compared with the original magma as approximated above (B). The results of this comparison are tabulated here:—

TABLE III.

	1.	2.	A.	B.	Norm of B.		
SiO_2 .	48·0	50·7	52·3	47·2	Qu.		..
Al_2O_3 .	14·6	14·7	14·9	14·6	Or.		1·7
Fe_2O_3 .	0·5	3·8	18·2	8·4	Ab.		6·8
FeO .	9·5	11·2			An.		35·3
MgO .	12·5	4·6	..	15·2	Di.	Wo.	13·3
CaO .	12·3	9·0	7·0	13·5		En.	8·8
Na_2O .	1·2	2·2	2·8	0·8		Fs.	3·6
K_2O .	0·4	0·8	1·1	0·3	Hy.	En.	2·4
TiO_2 .	0·6	2·5	3·7	..		Fs.	1·1
P_2O_5 .	0·2	0·3	..	..	Ol.	Fo.	18·7
MnO .	0·2	0·2	..	..		Fa.	8·3
Total .	100·0	100·0	100·0	100·0	Total .		100·0

1. Composition original olivine-dolerite magma (B).
2. Composition Elephant's Head tholeiite (analysis No. 70).

A. Material to be added to original magma, to obtain the tholeiite.

B. Material to be subtracted from original magma, to obtain the tholeiite.

It is clear that the composition of B is an entirely reasonable one, whereas that of A does not compare with any known, natural rock. The norm of B corresponds to a rock, composed of basic plagioclase, diopsidic pyroxene, and magnesian olivine. These constituents were all found as phenocrysts in the chilled modifications of the olivine-dolerite magma.

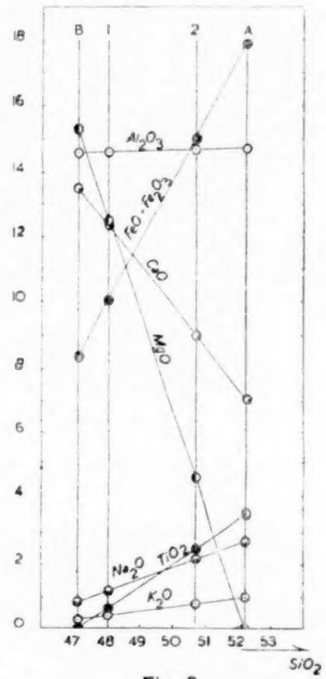


Fig. 6

Addition and subtraction diagram of the original Olivine-dolerite magma (1) and the Elephant's Head Tholeiite (2).

Thus there appears to be some justification for the assumption, that the tholeiite was derived from the olivine-dolerite magma by the separation of crystals of olivine, plagioclase, and pyroxene (together probably with some picotite), in depth. It is noted that, although the above constituents crystallised under intratelluric conditions, the olivine-dolerite magma first precipitated olivine and a little chromiferous magnetite after emplacement.

VII. Petrogenesis.

A. *The Origin of the Variolitic Picrite.*

Rocks with variolitic structures are commonly ascribed to rapid cooling. The formation of a similar variolitic picrite from the Island of Skoay

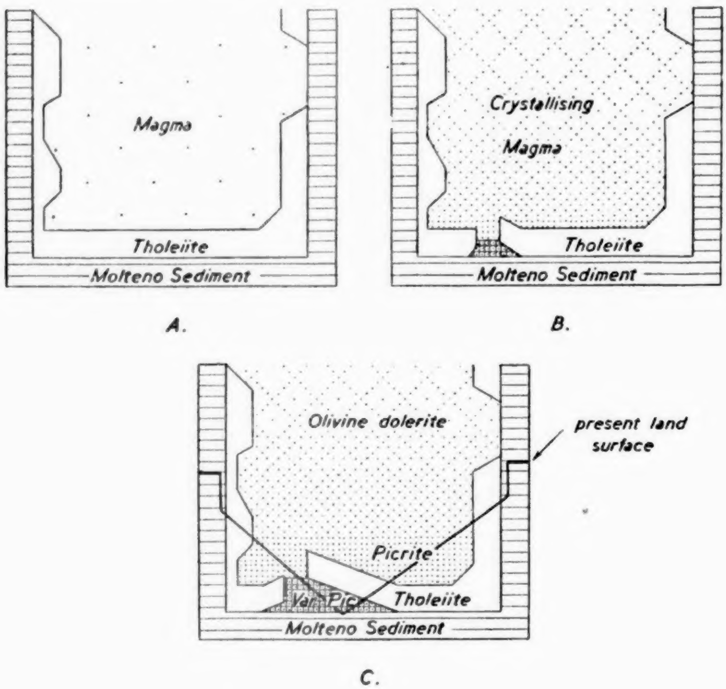


Fig. 7

Illustrating stages in the Stoping Process which resulted in the formation of the Variolitic Picrite

(Harker, 1904, p. 470) was likewise due to sudden chilling. Bowen (1928, pp. 146–147) is most pertinent in his comment: "It is not reasonably to be supposed that the large olivine crystals of this rock were formed under the same conditions as a groundmass which is but a step removed from

the spherulitic state of crystallisation. Plainly the groundmass was the only portion of the rock that was liquid when it was finally chilled on intrusion."

In the present case, the evidence strongly suggests that the picrites of the dike were formed by gravitational accumulation of olivine, crystallising in excess of the stoichiometric proportion. The chilled modifications of the olivine-dolerite magma, bordering dolerites and picrites alike, are normal basalts, containing but 3 per cent. of olivine. The variolitic picrite occurs in only one locality, partly surrounded by normal picrites. Thus it did not seem probable, that the magma already contained 30 per cent. of solid olivine upon intrusion (this being the amount of olivine phenocrysts in the variolitic rock). Neither are the field relations at Mount Fred clarified by this assumption.

An alternative is, that a portion of the crystallising magma was suddenly chilled, when olivine had already commenced crystallisation and had settled in considerable quantities. The remaining portion apparently continued to crystallise undisturbed. The above process can easily be effected by the upstoping of a portion of the protective tholeiite mantle, and freezing of the differentiated magma in the gap. This picture forms a reasonable explanation of the formation of the variolitic picrite, while the field relations at Mount Fred are also taken into account (fig. 7, *a–c*). The Calamity Hill picrites are remarkably regular as regards changes in mineral proportions with decreasing olivine content. No such regularity is present in the Mount Fred series. The latter, moreover, is constantly richer in plagioclase, and poorer in pyroxene, than the Calamity Hill series. The variolitic picrite shows less plagioclase and more pyroxene than corresponds with the Calamity Hill series. Subtraction of a portion of the magma, by freezing to variolitic picrite, would therefore result in such differences as are shown in the Mount Fred series.

B. *Mechanism of Differentiation.*

A comparison of the igneous rocks of the dike and the sheet shows that the former contains basic and medium differentiates, whereas the sheet contains medium and "acid" rocks. It seems thus highly probable that the dike acted as the feeder of the sheet. All the evidence points towards the formation of the picrites through gravitational settling of early crystallising olivine, which accumulated at the bottom of major undulations in the dike floor. Conditions were ideal for the separation of early formed, heavy crystals, as settling was controlled both by the flow of the magma and the specific gravity of the crystals. The accumulation of solid particles caused a difference in the shape of the flow-front of the magma, wherever settling occurred in bulk. In the lower parts of

the accumulations, magma-flow had virtually stopped. Hence large, poikilitic plagioclase crystals were formed here. Higher up, some flow of magma persisted, and thus small, lath-shaped plagioclase crystals are found in the higher picrites.

In the sheet, a slow upward migration of the later rest-magmas is implied by the petrography of the rocks. This seems to have been effected by gravitative action, as indicated by Scholtz (1936, p. 203) in his study of the Insizwa lopolith. Probably such rest-magmas were heavily charged with volatile constituents. In this connection it is noteworthy, that many intrusions develop pegmatitic facies as the iron-rich phase is approached. The Palisade intrusion (Walker, 1940) may be taken as a typical example. The formation of pegmatites appears to be more common than the production of such extreme iron-rich differentiates as are recorded by Deer and Wager (1939 *b*) and the present author. The conditions promoting the one phase over the other are, however, still unknown. In both instances the final trend of crystallisation is towards the development of rocks rich in soda, potash, and silica, and of felsic composition.

VIII. Form of the Dike and Mechanism of Intrusion.

The Elephant's Head dike shows three features, which distinguish it from the usual dike-intrusion:—

1. It has a flat or slightly domed roof, and in places apparently a floor, in addition to two parallel, vertical walls.
2. It is sinuous in a longitudinal section.
3. Its contents show great variations in type and chemical composition.

There is much evidence, indicating that the dike possesses a "floor" as well as a "roof." The origin of the picrites through gravitation of olivine, and their occurrence in the hollows of the dike's undulations, fully confirm this view. The origin of the variolitic picrite and the field relations at Mount Fred are, likewise, best interpreted in terms of the dike being floored. Finally, Schwarz (1902, p. 50) reports that, in the stream-bed at Robertdale, "there is a gap in the dolerite, and the sandstone beds pass quite undisturbed and horizontally from side to side of the great dike." Unfortunately the author was prevented from visiting this locality, but considers that the floor of the dike is actually exposed there.

The undulatory character of the dike-profile is accentuated in certain strata. In the Hanover-Calamity Hill stretch, gentle transgressions are inferred from the grain-size and the composition of the exposed rocks. Through the Molteno beds the transgressions are astonishingly steep, as exemplified by the major undulation at Elephant's Head. Farther west

exposures are mostly continuous, but here too rather deep undulations are inferred.

Records of irregularly profiled dikes are rare. The well-known Cleveland dike of northern England forms a notable exception. The intrusion shows little sign of differentiation (Holmes, 1929, p. 39), and there is no justification to consider the dike floored. Buie (1941, pp. 1780–1798) described a remarkable differentiated intrusion in the Highwood Mountains. Somewhat modified Buie's "Headed dike" reproduces the essential features of the Elephant's Head intrusion. Daly (1933, pp. 89–90) briefly discussed the ribbon-like apophyses from the differentiated sill at Pigeon Point (Minnesota). The apophyses show clean-cut, rectangular cross-sections, with flat or slightly domed roofs. The intrusions described are very small, but Daly does not exclude the production of similar features on a much larger scale.

The Elephant's Head dike probably originated in a series of shallow faults, which may have deepened towards Basutoland. The fact that several other dikes strike against the intrusion, but fail to cross it, nor continue on the other side, further supports this view.

The faults were vertical or steeply inclined, and may have differed in depth, thus forcing the dike to assume its sinuous character. As suggested by du Toit,* such dike-faulting might have been caused by stresses, produced by the introduction of unequal quantities of magma under the sedimentary roof. The thickly bedded, coarse Molteno sediments were particularly subject to pronounced faulting and the dike undulates strongly in these beds. The finer-bedded Burghersdorp sediments were not so well suited for such fracturing. Hence the earlier tholeiite magma stopped a short distance from the Molteno beds. The later olivine-dolerite magma evidently possessed a greater impetus and advanced further into the Burghersdorp strata. Undulations in these beds are gentle, while, significantly, the sheet was injected along the first major argillaceous horizon encountered by the magma. Viewed in this manner, the flow of magma is inferred to be from Basutoland down towards New Amalfi; the dike acting as a feeder for the sheet. Thus the two intrusions might well serve as an example for the "descensional lit-par-lit stoping" mode of injection of the Karroo magma, suggested by du Toit (1920, p. 33).

IX. Metasomatism of Burghersdorp Sandstone.

A. *Petrography.*

The normal metasomatic granophyre consists chiefly of quartz, micropegmatite, plagioclase, and pyroxene or biotite. Plagioclase (An. 28)

* Personal communication.

forms stumpy, zonal crystals, surrounded by haloes of micropegmatite. Some oligoclase occurs as irregular, untwinned grains in association with quartz. Pyroxene is of the monoclinic variety only and builds subophitic, elongated crystals of green or purple-brown colour. The optical properties are 2V : 54°, $\gamma \wedge c$: 45°, γ : 1·755. In many rocks clinopyroxene is partly or wholly replaced by a nearly black biotite (γ : 1·679). Black ore occurs as skeletal masses. Zircon and apatite are accessories. The rocks suffered intense deuteric alteration. Plagioclase is cloudy, the feldspar of the micropegmatite indeterminable. Clinopyroxene is marginally altered to hastingsite and brown serpentine. Radiating needles of pectolite are often found filling small vesicles.

The cores of sandstone xenoliths in the granophyre band show a mosaic of interlocking grains of quartz and feldspar with a few small patches of finely developed micropegmatite. Iron ore granules and aggregates of golden-brown serpentine occur in addition. Sphene and zircon predominate in the heavy residues, while apatite, garnet, and tourmaline are of rarer occurrence. Comparison with several sections of original and contact-metamorphosed Burghersdorp sandstone reveals a close agreement. Some sandstones are finer grained and more argillaceous, but the majority are fairly pure, feldspathic, arenaceous rocks. The differences in the Burghersdorp sandstones are reflected in certain variations in the make-up of the resulting metasomatic granophyres. The proportions of quartz, micropegmatite and plagioclase in these rocks are subject to appreciable changes. As noted, clinopyroxene is in some granophyres largely replaced by biotite.

The transitional zones around xenoliths are to be considered next. The first transition is a white rock with irregular, drawn-out purple patches. The white matrix consists of a coarse, altered micropegmatite, through which rods of iron ore and irregular green pyroxene crystals are scattered. The purple patches show a mosaic of minute granules of plagioclase (An. 41) and purple clinopyroxene (γ : 1·726). The second transitional zone, bordering outwards against the normal granophyre, is of more uniform composition and wider than the first. Essentially it is a fine-grained granophyre, showing slender plagioclase laths, green pyroxene prisms, and stumpy rods of iron ore, while the remainder consists of quartz and micropegmatite. The pyroxene is subophitic and crystals may include grains of quartz and apatite. Traces of the purple patches are preserved as small accumulations of plagioclase and purple-green pyroxene, now of larger dimensions.

B. *Chemistry.*

The sedimentary core of a xenolith, the second transitional zone around this xenolith, and the normal granophyre nearby, were analysed by Mr. F. Herdsman (analyses 49, 50, and 51). These show clearly that the process of converting the sandstone was a highly selective one. The irregular variation of the oxides in the three analyses precludes the possibility of the granophyre having been formed by simple admixtures of sandstone, and either the original olivine-dolerite magma or differentiated portions of that magma. The fact that the granophyres occur in a well-defined zone in the upper parts of the sheet, and show sharp boundaries against the dolerites above and below the zone, also indicates the metasomatic origin of these rocks. Clear-cut margins of transitional modifications are regarded by Reynolds (1936, p. 403) as typical for pyro-metasomatism.

In order to obtain an idea of the losses and gains of material effected by the process, the analyses were recalculated to constant volumes.

TABLE IV.

	SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MgO.	CaO.	Na_2O.	K_2O.	H_2O.	TiO_2.	P_2O_5.	MnO.
49 . .	190·0	30·7	3·5	3·7	0·5	0·7	5·4	0·7	3·0	0·5	..	..
50 . .	171·6	38·3	3·0	17·8	4·9	10·7	13·7	5·2	3·6	4·1	0·3	0·3
51 . .	171·8	29·3	10·3	25·7	1·7	13·9	7·8	7·3	5·6	4·2	0·8	0·6
Gains and Losses of 50, 51, as compared with 49.												
50 Loss .	18·4	..	0·5	..	..	..	..	4·5	..	..	..	..
50 Gain .	..	7·6	..	14·1	4·4	10·0	8·3	..	0·6	3·6	0·3	0·3
51 Loss .	18·2	1·4	..	..	..	..	..	2·4	..	..	..	..
51 Gain .	..	..	6·8	22·0	1·2	13·2	2·4	..	2·6	2·7	0·8	0·6

As shown, the losses and gains sustained are highly variable. The author can but quote Miss Reynolds, that: "The circumstances which contributed towards the present distribution of the elements in the transfused xenoliths include: (*a*) sequence of introduction into the xenoliths, (*b*) relative rate, or power of diffusion, through the xenoliths, (*c*) sequence (in both time and space) of fixation by the xenoliths" (1936, p. 398). In the present case the responsible magma was highly differentiated. Hence it is only reasonable to presume that the emanations, derived from this magma, would likewise be of a constantly changing character. With all these variable factors operating it is scarcely surprising that the resulting

metasomatic granophyres are of such different compositions. Indeed, the irregular variation of the oxides is a strong indication, that the conversion of the sandstone was produced by a molecular, metasomatic process.

The sandstone was apparently rendered plastic by heat and by the emanations derived from the magma. The habit of the pyroxenes and the lack of sieve textures show that the crystals grew in a viscous medium, enabling them to push aside adjacent grains. The granophyric veins in the dolerite indicate that the mass eventually acquired rheomorphic properties. Signs of mingling or gradation between the two rock-types are, however, wholly lacking. Hence the granophyre was at no time completely liquid, and only acquired the mobility of a plastic, highly viscous substance.

X. Conversion of Molteno Sediment.

A. *Petrography.*

The arenaceous horizons of the Molteno beds vary from coarse, pebbly, felspathic grits to medium-grained sandstones. The rocks consist mainly of quartz, microcline, orthoclase, and plagioclase, together with small amounts of iron ore and yellow serpentine. Zircon, sphene, and garnet are the heavy residue minerals. More argillaceous varieties show a grey-brown matrix, while serpentine and ores are more abundant.

Contact-metamorphism produced a regeneration of the clastic grains of quartz and feldspar. These form large interlocking crystals, surrounded by smaller individuals. The larger grains show a patchy extinction, while their composite origin is also indicated by sutured lines traversing the crystals. A little interstitial micropegmatite occurs in addition.

The rocks, affected by the tholeiite magma, show great differences in their mineralogical make-up. The products of the more arenaceous horizons are medium-grained granophyres, consisting chiefly of quartz, micropegmatite, plagioclase, and a pale-coloured clinopyroxene. Both plagioclase (An. 58) and pyroxene ($2V : 48°$, $\gamma \wedge c : 45°$, $\gamma : 1{\cdot}712$) are markedly elongated. The rocks frequently contain corroded and rounded lumps of undigested quartzite or xenocrysts of quartz and feldspar. In the products of more argillaceous horizons, pyroxene is largely replaced by hornblende or biotite, while plagioclase occurs in smaller amounts. All the rocks are intensely altered, plagioclase being cloudy, while pyroxene also becomes cloudy and grey in colour. On subsequent alteration the latter alters to biotite, hornblende, chlorite, and serpentine.

Small calcareous pellets in the argillaceous sediment are represented by aggregates of calc-silicate minerals in the converted sediment. These

Table V.

Volumetric Analysis.

	Tholeiite.	Picrites.								Olivine-Dolerites.							Pigeonite-Dolerites.			Iron-rich Dolerites.				Granophyres from Burghersdorp Sed.				Gran. from Molteno Sed.	
		Calamity Hill.				Mount Fred.																							
Index Number	70.	37.	39.	41.	42.	11.	14.	10.	9.	67.	43.	44.	8.	29.	58.	25.	79.	78.	46.	20.	56.	52.	18.	50.	51.	53.	81.	33.	77.
Olivine	0·5	61·2	56·1	34·5	23·6	49·4	44·1	38·2	21·9	12·5	3·9	2·6	6·3	3·0	10·3	6·6	4·7	1·7	1·3	..	..	0·5	1	..	..	..	..	..	..
Plagioclase	37·8	16·7	21·2	36·1	44·6	24·6	30·2	44·7	52·9	42·4	46·3	53·2	54·6	58·2	50·7	51·3	51·7	46·3	51·1	44·8	39·0	36·2	26	10·9	22·0	24·9	37·5	24·4	22·8
Pyroxene	23·8	14·0	17·3	24·0	27·9	21·3	18·9	15·0	23·6	36·0	39·0	38·4	33·9	33·8	33·9	34·8	31·1	38·9	35·5	35·4	26·5	23·3	7	21·9	11·5	9·5	5·7	18·3	17·5
Iron Ore	8·6	5·5	2·9	2·9	2·4	4·7	4·0	1·7	1·4	5·4	4·1	2·0	2·1	2·0	1·8	1·9	2·2	2·3	1·8	1·8	5·8	6·2	5	2·2	3·7	3·9	2·2	2·2	2·6
Biotite and Amphibole	5·2	2·6	2·5	2·5	1·5	..	2·8	0·4	0·2	3·7	0·8	1·1	1·2	1·2	0·4	1·1	1·3	1·9	0·7	4·8	7·6	10·2	2	2·3	3·2	3·8	7·0	5·6	6·8
Micropegmatite and Quartz	..	..	..	..	..	..	..	..	..	..	5·9	2·7	1·9	1·8	2·9	4·3	9·0	..	..	12·7	21·1	19·7	51	62·7	52·5	50·3	43·5	49·5	50·3
Mesostasis.	24·1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8·9	9·6	..	..	..	..	..	..	..	..	..	..
Brown Serpentine	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·9	8	..	7·1	7·6	4·1	..	..

70. Tholeiite, top of Elephant's Head peak.
37–42. Picrites, Calamity Hill, towards top of hill (vert. dist. 100 ft.).
11. Variolitic picrite, valley on Mount Fred.
14–9. Picrites, Mount Fred, towards top of hill W. of road (vert. dist. 250 ft.).
67. Olivine-dolerite, foot of Elephant's Head peak.
43–44. Olivine-dolerites, dike, from Calamity Hill towards Taylorville.
8. Olivine-dolerite, Mount Fred, top of hill W. of road.
29. Olivine-dolerite, dike, poort on Mahainkwe.
58. Olivine-dolerite, dike, behind house, Hanover.
25. Olivine-dolerite, sheet, 1 mile E.N.E. of Umzimvubu bridge.
79. Pigeonite-dolerite, sheet, Katfontein.
78. Pigeonite-dolerite, inclined sheet, Sydenham.
46. Pigeonite-dolerite, Mooi Plaats sheet, ½ mile E. of Taylorville.
20. Quartz-dolerite, sheet, ½ mile W. of Umzimvubu bridge.
56. Quartz-dolerite, sheet, 200 ft. below granophyre zone, 1½ miles N. of New Amalti post office.
52. Fayalite-quartz-dolerite, sheet, 100 ft. below granophyre zone, 2 miles N. of New Amalti post office.
18. Fayalite-hedenbergite-granophyre, sheet, just below granophyre zone, The Springs.
50. Second transitional zone around sandstone xenolith in granophyre band, kopje 2 miles N. of New Amalti post office.
51. Metasomatic granophyre of zone, 2 ft. from 50.
53. Metasomatic granophyre of zone, 50 yards S. of 50.
81. Metasomatic granophyre of zone, The Springs, overlying 18.
33. Converted Molteno sediment of Indwe horizon, roof of dike, Calamity Hill.
77. Converted Molteno sediment of Indwe horizon, S. side of dike, Elephant's Head.

are always perfectly fresh, even if the surrounding rock is intens..y altered. Among the calc-silicates epidote, clinozoisite, idocrase, prehnite, tremolite, and sphene were recognised. A mixed rock from Elephant's Head shows veins and irregular areas of Molteno quartzite, contained in a modified, tholeiitic base. The latter consists mainly of euhedral clinopyroxene

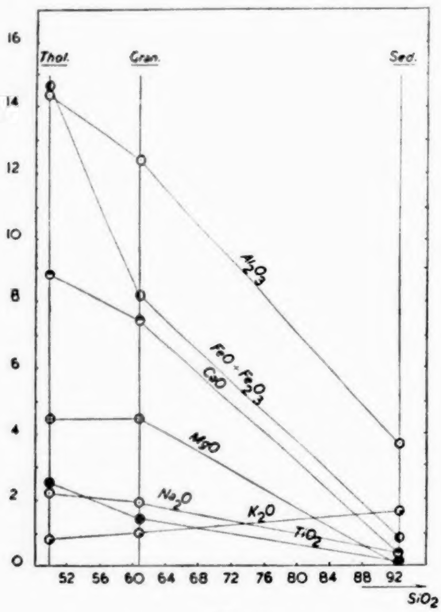


Fig. 8

Variation of the reaction series

Tholeiite – Granophyre – Molteno Sandstone.

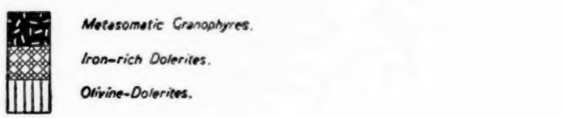
(γ : 1·725), up to 1 mm. diameter. The remainder shows cloudy, tabular feldspar, skeletal ore, and a coarse mesostasis. Bordering the sediment many prismatic, pale-coloured pyroxenes occur, arranged perpendicular on the surface. Similar pyroxenes occur within the sediment, at points where some mingling with igneous material has taken place. The mineral has γ : 1·721.

B. *Chemistry.*

A coarse-grained Molteno sandstone from Mahainkwe poort, and a medium-grained granophyre from Calamity Hill were analysed by Mr. F.

Fig. 9

MAP OF THE NEW AMALFI SHEET.



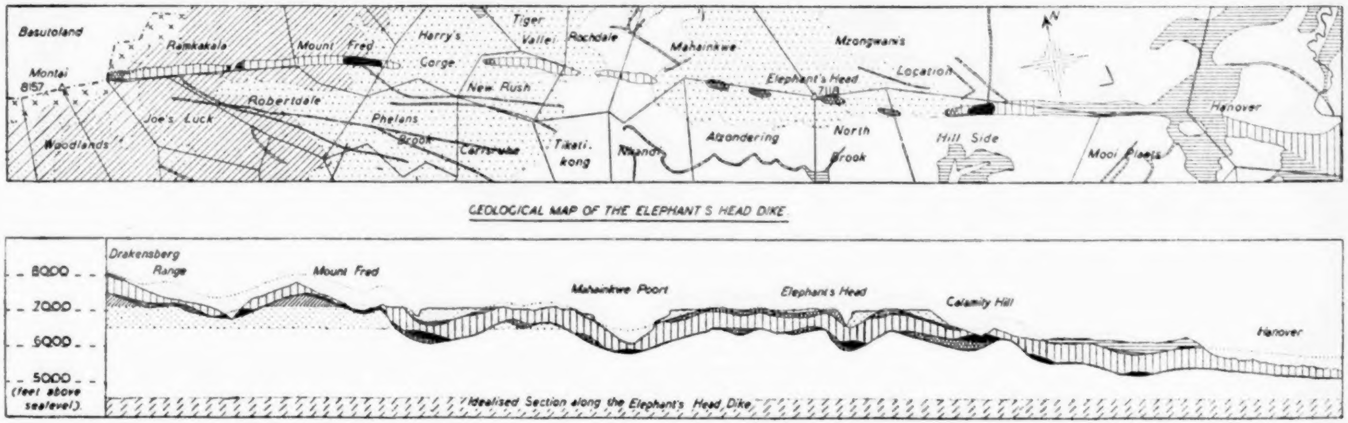
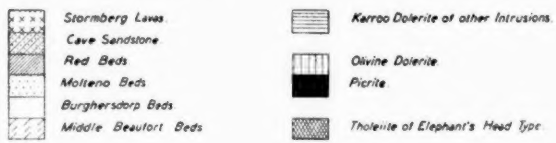


Fig. 10

INDEX



SCALE : 0 1 2 3 4 Miles

The width and the height of the Dike were exaggerated to show the distribution of the various Rock Types.

Herdsman (analyses 31 and 33). The analyses are represented, together with the Elephant's Head tholeiite, in fig. 8. It is plain that the available data are insufficient to draw definite conclusions. The analysed specimens are from different localities and not, as in the previous chapter, from one and the same rock-sequence. Yet the analysed Molteno sandstone belongs to the Indwe horizon, as does the Calamity Hill sediment. The unconverted lumps of Molteno quartzite, occurring in the granophyres at Calamity Hill, are identical with the analysed sediment from Mahainkwe poort. Finally, the tholeiitic rocks are very uniform in composition and the slides from Mount Fred, Elephant's Head, and Calamity Hill only show differences in the degree of weathering. Thus within certain limits, inferences can safely be drawn from the three analyses. Here again the non-linear variation of the oxides is the most striking feature. Other evidence also suggests that the conversion of Molteno sediment was principally metasomatic. The granophyres occur in definite zones. Traces of the original bedding are preserved in the converted rocks. Calcareous pellets in the sediment are reproduced as kernels of calc-silicate minerals in the granophyres. All these characters were recorded in several other Karroo examples of metasomatism (Walker and Poldervaart, 1942 *b*).

The diagram shows that the tholeiitic magma gained SiO_2 and K_2O, while it lost in all other constituents. Losses are particularly heavy with respect to Al_2O_3, CaO, and FeO. These losses are reflected in the mixed rock of Elephant's Head, where there is a lack of plagioclase near the sandstone inclusions, while an iron-poor clinopyroxene is formed instead.

XI. Conclusions.

The following points are now regarded as established:—

1. The Elephant's Head dike is roofed and probably floored. A longitudinal section shows an undulatory profile. The undulations are more marked when cutting some strata than others.

2. The dike was formed by the injection of a tholeiitic magma, followed by the intrusion of olivine-dolerite magma. The latter also gave rise to the New Amalfi sheet. The dike was indeed the feeder of this sheet.

3. The olivine-dolerite magma became differentiated upon crystallisation. Differentiation was effected by settling of olivine, followed by pronounced crystal-fractionation in the rest-magma.

4. During the middle stages of crystallisation, differentiation proceeded towards iron enrichment. After reaching a maximum concentration in iron, differentiation continued towards enrichment in soda, potash, alumina, and silica.

5. A block of Burghersdorp sandstone was stoped down from the upper

TABLE VI.

Chemical Analyses.

Index Number.	70.	39.	11.	58.	25.	20.	52.	18.	49.	50.	51.	31.	33.
SiO_2	49·80	42·78	40·96	49·02	50·56	53·65	52·41	63·72	76·92	62·64	61·84	92·68	60·88
Al_2O_3	14·38	7·06	5·84	15·88	16·42	14·62	12·23	11·56	12·38	13·96	10·52	3·65	12·42
Fe_2O_3	3·67	0·51	1·61	0·17	0·42	0·93	3·53	1·64	1·39	1·12	3·66	trace	0·33
FeO	11·03	12·48	10·31	8·74	9·71	11·18	12·86	8·74	1·45	6·54	9·24	0·87	7·86
MgO	4·52	31·02	30·04	9·77	7·78	4·76	2·62	0·69	0·22	1·83	0·56	nil	4·52
CaO	8·82	3·84	4·60	13·86	9·88	8·48	8·48	4·20	0·28	3·91	4·97	0·30	7·44
Na_2O	2·23	0·51	0·62	1·42	1·92	2·50	2·01	2·92	2·17	5·02	2·83	0·36	1·96
K_2O	0·82	0·33	0·14	0·32	0·57	0·74	0·85	2·96	3·88	1·90	2·58	1·69	1·01
H_2O+	1·66	0·92	4·72	0·28	0·86	0·96	0·92	1·34	0·77	1·02	1·82	0·12	1·41
H_2O-	0·15	0·09	0·03	0·09	0·24	0·18	0·14	0·25	0·39	0·28	0·19	0·08	0·20
TiO_2	2·54	0·49	0·79	0·62	1·28	1·49	3·14	1·38	0·20	1·53	1·51	0·10	1·44
P_2O_5	0·29	trace	0·04	0·12	0·15	0·12	0·23	0·19	trace	0·11	0·34	trace	0·09
MnO	0·16	0·20	0·24	trace	0·22	0·19	0·26	0·18	trace	0·13	0·23	trace	0·16
CO_2	trace	nil	nil	nil	nil	nil	0·12	nil	trace	0·18	trace	nil	0·29
Total	100·07	100·23	99·94	100·29	100·01	99·80	99·80	99·77	100·05	100·17	100·29	99·85	100·01
Norms.													
Qu.	6·18	..	..	..	0·66	6·54	12·82	22·15	48·35	13·62	22·50	82·80	21·12
Or.	5·00	1·67	0·78	1·78	3·34	4·45	5·28	17·57	22·69	11·12	15·46	10·01	6·17
Ab.	18·34	4·19	5·24	12·15	16·24	20·96	16·87	24·73	18·18	42·54	23·89	3·14	16·56
An.	26·97	16·40	12·79	35·97	34·47	26·41	21·85	9·67	1·33	9·82	8·28	1·39	22·10
Cor.	..	..	..	..	..	..	..	..	4·23	..	..	0·71	..
Di. Wo.	6·26	1·16	4·04	13·43	5·68	6·26	7·71	4·31	..	3·16	5·99	..	5·08
Di. En.	2·90	0·80	2·98	7·93	3·00	2·50	2·34	0·57	..	1·11	0·70	..	2·43
Di. Fs.	3·30	0·26	0·66	4·81	2·51	3·83	5·69	4·15	..	2·13	5·90	..	2·57

Hy. { En.	8·40	7·00	5·47	6·56	16·40	9·40	4·21	1·16	0·55	3·46	0·70	..	8·87
Hy. { Fs.	10·16	1·98	1·20	3·98	13·20	13·86	10·22	8·52	1·07	6·56	5·92	1·45	9·39
Ol. { Fo.	..	48·86	46·66	6·86	..	..	..	..	..	..	..	..	..
Ol. { Fa.	..	15·50	11·36	4·77	..	..	..	..	..	..	..	..	..
Il.	4·71	0·91	1·52	1·25	2·43	2·89	5·99	2·68	0·46	2·93	2·90	0·15	2·80
Mt.	5·34	0·70	2·32	0·23	0·70	1·39	5·17	2·41	2·07	1·67	5·34	..	0·53
Ap.	0·67	..	0·14	0·34	0·34	0·34	0·37	0·34	..	0·34	0·80	..	0·30
H_2O	1·81	1·01	4·75	0·37	1·10	1·14	1·06	1·59	1·16	1·30	2·01	0·20	1·61
$CaCO_3$	..	..	..	..	..	..	0·26	..	..	0·44	..	..	0·68
Total	100·04	100·44	99·91	100·43	100·07	99·97	99·84	99·85	100·09	100·20	100·39	99·85	100·21

Modes.

Olivine	0·5	60·2	53·2	12·3	8·0	..	0·6	1	..	..	..	..	..
Plagioclase	33·4	16·6	19·3	44·3	45·5	40·5	31·7	24	×	9·9	20·1	×	23·2
Pyroxene	26·5	17·1	21·0	37·2	38·8	40·4	26·4	9	..	26·7	14·1	..	21·9
Iron Ore	13·5	4·0	6·5	2·7	3·0	2·9	9·6	8	×	3·7	6·2	×	3·7
Biotite + Amphibole	5·6	2·1	..	0·4	1·1	4·2	10·9	2	..	2·8	3·7	..	5·7
Micropegmatite + Quartz	..	..	..	3·1	3·6	12·0	16·6	47	×	56·9	48·0	×	45·5
Mesostasis	20·5	..	..	..	..	..	..	..	..	..	..	..	..
Brown Serpentine	...	..	..	..	..	..	4·2	9	×	..	7·9	×	..
Specific Gravity	3·00	3·26	3·19	3·06	3·00	2·92	2·98	2·68	2·48	2·73	2·79	2·60	2·80

70. Tholeiite, dike, top of Elephant's Head peak.
39. Picrite, dike, E. of road, Calamity Hill.
11. Variolitic picrite, dike, valley on Mount Fred.
58. Olivine-dolerite, dike, behind house, Hanover.
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52. Fayalite-quartz-dolerite, sheet, 100 ft. below granophyre band, 2 miles N. of New Amalfi post office.
18. Fayalite-hedenbergite-granophyre, sheet, just below granophyre band, The Springs.
49. Burghersdorp sandstone, core of xenolith, granophyre zone, kopje 2 miles N. of New Amalfi post office.
50. Second transitional zone around 49.
51. Normal granophyre of zone, 2 feet from xenolith 49.
31. Metamorphosed Molteno grit, Indwe horizon, poort on Mahainkwe.
33. Molteno grit of Indwe horizon, converted to granophyre, roof of dike, W. of road, Calamity Hill.

contact of the sheet. Upon immersion in the magma the sandstone was converted into granophyric rocks of igneous appearance.

6. The process of conversion of Burghersdorp sandstone to granophyre was metasomatic. The magmatic emanations were released over a prolonged period, extending well into the hydrothermal stage.

7. Along the dike, the Molteno sediments were, likewise, converted to granophryic rocks. These granophyres differ in appearance and composition from the rocks originating in the metasomatism of Burghersdorp sandstone. The magma, responsible for such conversion, was the tholeiitic magma.

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EXPLANATION OF PLATES.

$\times$ 10·5. Ordinary Light.

PLATE I.

1. Tholeiite of Elephant's Head (70). Hypidiomorphic pyroxene, plagioclase laths, interstitial mesostasis and abundant titaniferous ore.
2. Picrite of Calamity Hill (39). Euhedral olivine, poikilitic plagioclase and pyroxene, octahedral chromiferous ore and a few scraps of reddish-brown biotite.
3. Variolitic Picrite of Mount Fred (11). Olivine in two generations, and octahedral chrom-magnetite. A variolitic groundmass of plagioclase and clinopyroxene.
4. Olivine-Dolerite of Hanover (58). Large crystals of olivine, plagioclase laths and subophitic pyroxene. As accessories a little interstitial micropegmatite, skeletal ore and brown biotite.

PLATE II.

1. Quartz-Dolerite (20). Subophitic augite in two generations, plagioclase laths and interstitial micropegmatite and quartz. Skeletal ore and biotite as accessories.
2. Fayalite-quartz Dolerite (52). Subophitic ferroaugite in two generations, broad plagioclase crystals and interstitial micropegmatite and quartz. Iron-rich olivine and orthopyroxene in association with skeletal ore. Brown hornblende replacing biotite.
3. Metasomatic Granophyre (51). Green and purple clinopyroxene, broad plagioclase crystals and abundant micropegmatite and quartz. Skeletal ore, hastingsite and brown serpentine as minerals of late formation.
4. Converted Molteno Grit (33). A corroded lump of quartzite in grey granophyre. Note the marked elongation of the pyroxene and plagioclase crystals.

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Arie Poldervaart. *Neill & Co., Ltd.*

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THE DETERMINATION OF THE HORIZONTAL COMPONENT OF THE EARTH'S MAGNETIC FORCE AT THE MAGNETIC OBSERVATORY, HERMANUS, UNION OF SOUTH AFRICA.

By A. OGG, B. GOTSMAN, and A. M. VAN WIJK.

(With two Text-figures.)

(Read November 18, 1942.)

The purpose of this paper is to discuss the theory of the Schmidt Theodolite Magnetometer,* which is not generally known, and to compare the results of observations by different types of magnetometers, the constants of which have been determined at Washington, Abinger, and Copenhagen.

The types of magnetometers, which are available at the Magnetic Observatory, Hermanus, for determining the horizontal intensity (H) of the earth's magnetic field are:

(1) The Inductor Magnetometer of the Carnegie Institution, Washington (C.I.W. No. 17); (2) the Schmidt Standard Theodolite Magnetometer (Askania, No. 306643); (3) the Portable Coil Magnetometer (Cambridge Scientific Instrument Co. Ltd., No. L 62993); (4) the La Cour Quartz Horizontal Force Magnetometer (Q.H.M. Nos. 29, 30, and 58).

THE C.I.W. MAGNETOMETER AND THE SCHMIDT THEODOLITE MAGNETOMETER.

With these magnetometers the determination of the horizontal intensity (H) of the earth's magnetic field depends on a combination of deflection and oscillation experiments.

Deflection Experiment.

A magnet freely suspended with its axis horizontal is deflected by another magnet, whose axis lies in the same horizontal plane.

In 1890 Börgen developed the equation for the interaction between two magnets, placing no restrictions on their relative positions. Schmidt †

* Geomagnetism, Chapman and Bartels, vol. i, pl. ii, p. 79.

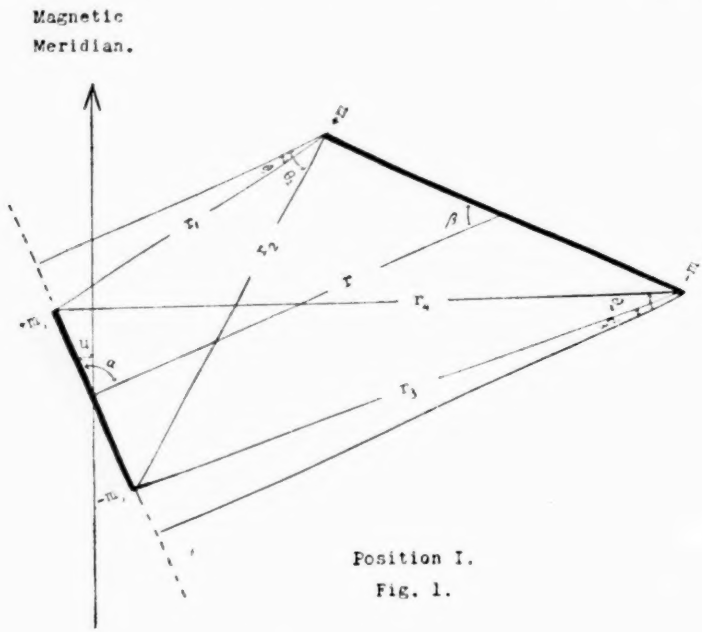
† Über die Bestimmung der Parameter von Stabenmagneten. Berichte über die Tätigkeit des Preuss. Meteorolog. Instituts im Jahre, 1926.

also developed the general deflection equation for two magnets lying in a plane.

Since the deflection experiments with these two instruments are made with the magnets in restricted positions, it is sufficient for the purpose of these experiments to derive a deflection equation which will be suitable for both instruments. The magnets can be regarded as schematic magnets or dipoles.

Magnets in Position I, fig. 1. $\alpha = 90°$.

Let m, m_1 be the pole strengths of the magnets; $2d$, $2d_1$ the pole distances or magnetic lengths; $2l$, $2l_1$ the ordinary lengths; M, M_1 the magnetic



Position I.
Fig. 1.

moments. Also let r be the distance between the centres of the magnets; r_1, r_2, r_3, r_4 the distances between the poles; θ_1, θ_2, θ_3, θ_4 the angles which the lines joining the poles of the magnets make with the perpendiculars from the poles of the deflecting magnet on the axis of the suspended magnet.

Let the suspended magnet make an angle u with the magnetic meridian, and the deflecting magnet make an angle β with the line joining the centres of the magnets, then

$$\mathrm{H} \sin u = \frac{m}{2}(\cos \theta_1 r_1^{-2} + \cos \theta_2 r_2^{-2} - \cos \theta_3 r_3^{-2} - \cos \theta_4 r_4^{-2}). \qquad (1)$$

But

$$r_1 \cos \theta_1 = r_2 \cos \theta_2 = (r - d \cos \beta) \qquad (2_1)$$

and

$$r_3 \cos \theta_3 = r_4 \cos \theta_4 = (r + d \cos \beta). \qquad (2_2)$$

Also

$$r_1^2 = (r - d \cos \beta)^2 + (d \sin \beta - d_1)^2 = (r - x)^2 + y^2, \qquad (3_1)$$
$$r_2^2 = (r - d \cos \beta)^2 + (d \sin \beta + d_1)^2 = (r - x)^2 + z^2, \qquad (3_2)$$
$$r_3^2 = (r + d \cos \beta)^2 + (d \sin \beta - d_1)^2 = (r + x)^2 + y^2, \qquad (3_3)$$
$$r_4^2 = (r + d \cos \beta)^2 + (d \sin \beta + d_1)^2 = (r + x)^2 + z^2, \qquad (3_4)$$

where

$$x = d \cos \beta, \qquad y = d \sin \beta - d_1, \qquad z = d \sin \beta + d_1.$$

From the equations (1), (2), and (3),

$$\mathrm{H} \sin u = \frac{m}{2}[\phi(r - x) - \phi(r + x) + f(r - x) - f(r + x)], \qquad (4)$$

where

$$\phi(r) = r(r^2 + y^2)^{-\frac{3}{2}} \quad \text{and} \quad f(r) = r(r^2 + z^2)^{-\frac{3}{2}}.$$

By Taylor's theorem,

$$\phi(r - x) - \phi(r + x) = -2x\phi'(r) - \frac{x^3}{3}\phi'''(r) - \frac{x^5}{60}\phi^{\mathrm{v}}(r) \; . \; . \; . \qquad (5)$$

and a similar equation for $(f(r - x) - f(r + x))$.

On substituting the differential coefficients of $\phi(r)$ and $f(r)$ and the powers of x, y, z, equation (4) becomes

$$\sin u = \lambda \cos \beta[2 - 6\mathrm{B} - 6\mathrm{A} \sin^2 \beta + 4\mathrm{A} \cos^2 \beta - 30 \cos^2 \beta(\mathrm{AB} + \mathrm{A}^2 \sin^2 \beta)$$
$$+ \tfrac{45}{4}(\mathrm{B}^2 + 6\mathrm{AB} \sin^2 \beta + \mathrm{A}^2 \sin^4 \beta) + 6\mathrm{A}^2 \cos^4 \beta \; . \; . \; .], \qquad (6)$$

where

$$\lambda = \frac{\mathrm{M}}{\mathrm{H}} r^{-3}, \qquad \mathrm{A} = d^2 r^{-2}, \qquad \text{and} \qquad \mathrm{B} = d_1^2 r^{-2}.$$

Equation (6) can be expressed in the form

$$\sin u = \lambda \cos \beta(2 + \tfrac{3}{2}\mathrm{A} - 6\mathrm{B} + \tfrac{45}{32}\mathrm{A}^2 - \tfrac{45}{8}\mathrm{AB} + \tfrac{45}{4}\mathrm{B}^2)$$
$$+ \lambda \cos 3\beta(\tfrac{5}{2}\mathrm{A} + \tfrac{105}{64}\mathrm{A}^2 - \tfrac{195}{8}\mathrm{AB}) \qquad (7)$$
$$+ \lambda \cos 5\beta(\tfrac{189}{64}\mathrm{A}^2).$$

The C.I.W. Magnetometer.

With this instrument the magnets are at right angles to one another in the first Lamont's position, $\beta = 0°$, and therefore

$$\sin u = 2\lambda(1 + 2\mathrm{A} - 3\mathrm{B} + 3\mathrm{A}^2 - 15\mathrm{AB} + \tfrac{45}{8}\mathrm{B}^2 \; . \; . \; .).$$

Since higher power of A and B are negligible, this equation may be written in the form

$$\sin u = 2\lambda(1 + \mathrm{P}r^{-2} + \mathrm{Q}r^{-4}), \qquad (8)$$

where P and Q are constants for the pair of magnets used with the instrument.

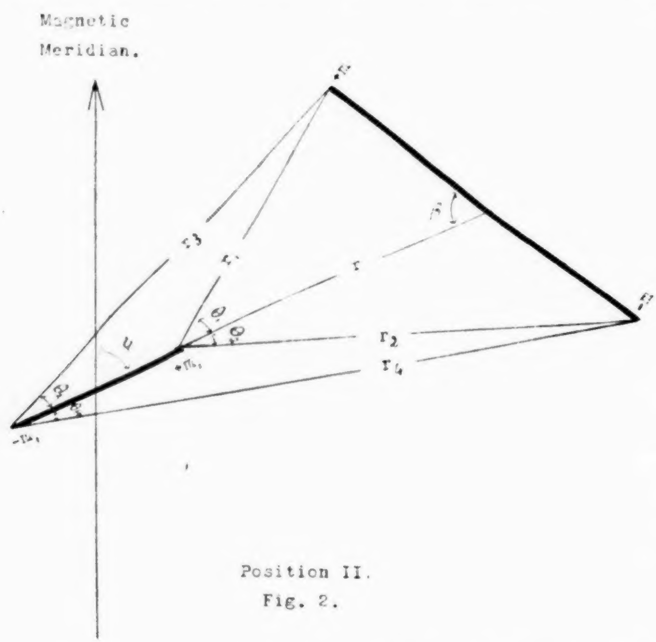
Let $$(1 + Pr^{-2} + Qr^{-4}) = k.$$

Since k, the *deflection coefficient* for distance r, is of dimensions 0 in length and the correction for temperature negligible, it is sometimes called the *deflection constant* for distance r. It may be determined (once for all) by measuring deflections at different distanesc or by other methods of standardisation.

With this instrument, in the ordinary determinations of H, deflections are taken at three distances.

Schmidt Standard Magnetometer.

With this instrument deflections are taken at one fixed distance and the angle β is varied. If n values of sin u are obtained with the magnets



Position II.
Fig. 2.

in Position I, fig. 1, for $\beta = 0°$ or $360°$, $\beta = \frac{360°}{n}$, $\beta = \frac{2 \times 360°}{n}$, $\beta = \frac{3 \times 360°}{n}$, etc., and these n values are developed by harmonic analysis as a trigonometrical series,

$$\sin u = c_1 \cos \beta + c_2 \cos 2\beta + c_3 \cos 3\beta + c_4 \cos 4\beta + c_5 \cos 5\beta + \ . \ . \ .$$
$$+ b_1 \sin \beta + b_2 \sin 2\beta + b_3 \sin 3\beta + b_4 \sin 4\beta + b_5 \sin 5\beta + \ . \ . \ .$$

then by equation (7),

$$c_1 = \lambda(2 + \tfrac{3}{2}\mathrm{A} - 6\mathrm{B} + \tfrac{45}{32}\mathrm{A}^2 - \tfrac{45}{8}\mathrm{AB} + \tfrac{45}{4}\mathrm{B}^2), \qquad (9_1)$$

$$c_3 = \lambda(\quad + \tfrac{5}{2}\mathrm{A} \qquad + \tfrac{105}{64}\mathrm{A}^2 - \tfrac{195}{8}\mathrm{AB} \qquad), \qquad (9_2)$$

$$c_5 = \lambda(\qquad\qquad + \tfrac{189}{64}\mathrm{A}^2 \qquad\qquad). \qquad (9_3)$$

These equations are not sufficient for a satisfactory determination of A and B, and deflections are also measured with the magnets in Position II, fig. 2.

Magnets in Position II, fig. 2. $a = 0°$.

If θ_1, θ_2, θ_3, θ_4 are the angles, which the lines joining the poles of the magnets make with the axis of the suspended magnet, then

$$\mathrm{H} \sin u = \frac{m}{2}(\sin \theta_1 r_1^{-2} + \sin \theta_2 r_2^{-2} + \sin \theta_3 r^{-2} + \sin \theta_4 r^{-2}) \qquad (10_1)$$

and

$$r_1 \sin \theta_1 = r_2 \sin \theta_2 = r_3 \sin \theta_3 = r_4 \sin \theta_4 = d \sin \beta; \qquad (10_2)$$

therefore

$$\mathrm{H} \sin u = \frac{\mathrm{M}}{4} \sin \beta(r_1^{-3} + r_2^{-3} + r_3^{-3} + r_4^{-3}). \qquad (10_3)$$

Also

$$r_1^2 = (r - d_1 - d \cos \beta)^2 + d^2 \sin^2 \beta = (r - x)^2 + z^2, \qquad (11_1)$$

$$r_2^2 = (r - d_1 + d \cos \beta)^2 + d^2 \sin^2 \beta = (r - y)^2 + z^2, \qquad (11_2)$$

$$r_3^2 = (r + d_1 - d \cos \beta)^2 + d^2 \sin^2 \beta = (r + y)^2 + z^2, \qquad (11_3)$$

$$r_4^2 = (r + d_1 + d \cos \beta)^2 + d^2 \sin^2 \beta = (r + x)^2 + z^2, \qquad (11_4)$$

where

$$x = d_1 + d \cos \beta, \qquad y = d_1 - d \cos \beta, \qquad z = d \sin \beta.$$

If

$$\phi(r) = (r^2 + z^2)^{-\frac{3}{2}},$$

then

$$\mathrm{H} \sin u = \frac{\mathrm{M}}{4} \sin \beta[\phi(r - x) + \phi(r + x) + \phi(r - y) + \phi(r + y)],$$

$$\mathrm{H} \sin u = \mathrm{M} \sin \beta\left[\phi(r) + \frac{x^2 + y^2}{4}\phi''(r) + \frac{x^4 + y^4}{48}\phi^{\mathrm{iv}}(r) \ . \ . \ .\right]. \qquad (12)$$

If $\phi(r)$, its differential coefficients, and powers of x, y, z are substituted in equation (12), it becomes

$$\sin u = \lambda \sin \beta(1 + 6\mathrm{B} + 15\mathrm{B}^2) + \sin \beta\mathrm{A}(-\tfrac{3}{2} \sin^2 \beta + 6 \cos^2 \beta)$$
$$+ \lambda \sin \beta\mathrm{AB}(-\tfrac{45}{2} \sin^2 \beta + 90 \cos^2 \beta)$$
$$+ \lambda \sin \beta\mathrm{A}^2(\tfrac{15}{8} \sin^4 \beta + 15 \cos^4 \beta - \tfrac{45}{2} \sin^2 \beta \cos^2 \beta), \qquad (13)$$

where λ, A, and B have the same values as in equation (6).

Equation (13) can be expressed in the form

$$\begin{aligned}\sin u = \lambda \sin \beta(1 + \tfrac{3}{8}\mathrm{A} + 6\mathrm{B} + \tfrac{15}{64}\mathrm{A}^2 + \tfrac{45}{8}\mathrm{AB} + 15\mathrm{B}^2)&\\ + \lambda \sin 3\beta(+ \tfrac{15}{8}\mathrm{A} + \tfrac{105}{128}\mathrm{A}^2 + \tfrac{225}{8}\mathrm{AB})&\\ + \lambda \sin 5\beta(\qquad + \tfrac{315}{128}\mathrm{A}^2 \qquad).&\end{aligned} \tag{14}$$

If n values of $\sin u$ are determined as in Position I and these are expressed as a trigonometrical series of the same form, then

$$b_1 = \lambda(1 + \tfrac{3}{8}\mathrm{A} + 6\mathrm{B} + \tfrac{15}{64}\mathrm{A}^2 + \tfrac{45}{8}\mathrm{AB} + 15\mathrm{B}^2), \tag{15_1}$$

$$b_3 = \lambda(\quad + \tfrac{15}{8}\mathrm{A} + \tfrac{105}{128}\mathrm{A}^2 + \tfrac{225}{8}\mathrm{AB}), \tag{15_2}$$

$$b_5 = \lambda(\qquad + \tfrac{315}{128}\mathrm{A}^2 \qquad). \tag{15_3}$$

Observations.

In order to develop the series in equations (7) and (14) as far as the term in 5β we require at least 12 values of $\sin u$. Harmonic analyses, however, have shown that sufficient accuracy is obtained by reducing the observed values of $\sin u$, corrected for temperature, induction, and the changes of H during observation, to three means.

Position I, fig. 1.

Let e_1 be the mean numerical value of $\sin u$ for $\beta = 0°$ and $180°$, e_2 the mean value for $\beta = \pm 30°$ and $180° \mp 30°$, and e_3 the mean value for $\beta = \pm 60°$ and $180° \mp 60°$, then

$$c_1 = \tfrac{1}{3}(e_1 + \sqrt{3}e_2 + e_3), \qquad c_3 = \tfrac{1}{3}(e_1 - 2e_3), \qquad c_5 = \tfrac{1}{3}(e_1 - \sqrt{3}e_2 + e_3). \tag{16}$$

Position II, fig. 2.

Let e_1 be the mean value of $\sin u$ for $\beta = \pm 30°$ and $180° \mp 30°$, e_2 the mean value for $\beta = \pm 60°$ and $180° \mp 60°$, and e_3 the mean value for $\beta = 90°$ and $270°$, then

$$b_1 = \tfrac{1}{3}(e_1 + \sqrt{3}e_2 + e_3), \qquad b_3 = \tfrac{1}{3}(2e_1 - e_3), \qquad b_5 = \tfrac{1}{3}(e_1 - \sqrt{3}e_2 + e_3). \tag{17}$$

By a combination of equations (16) and (17) with equations (9) and (15) the parameters of the magnets can be determined.

Magnets.

The Schmidt Magnetometer was obtained shortly before the declaration of war, but the deflecting magnets, which were designed to make the Q coefficient of equation (8) negligible, were detained at the Reichsanstalt, Berlin, for standardisation, and have not been available for these observations.

The two deflecting magnets of the Askania Portable Magnetometer (No. 578179), which gave suitable deflections with the Standard instrument, have been used instead. Both these magnets are hollow cylinders of the same dimensions, length 5·00 cm., external diameter 1·05 cm., internal diameter 0·74 cm., but of different magnetic moment.

The pole distances of these magnets have been determined by the methods described. For both hollow magnets the ratio of the magnetic length to the ordinary length is 0·83, while for the suspended magnet, a solid cylinder, 4·00 cm. long and 1·20 cm. diameter, the ratio is 0·80.

Chree * found for different types of magnets a ratio varying from 0·80 to 0·86. Börgen concluded from his experiments that the pole distance is on the average about 0·805 of the ordinary length, while Kohlrausch found to a close approximation a ratio $= \frac{5}{6} = 0{\cdot}83$.

Method of Observation.

The method, which has been described, is very complete, but is laborious both in observation and calculation. However, the number of observations can be reduced and the calculations simplified.

Equations (9) and (15) give

$$c_1 + b_1 - b_3 = 3\lambda(1 + \tfrac{35}{128}A^2 + \tfrac{35}{4}B^2 - \tfrac{75}{8}AB). \qquad (18_1)$$

If the parameters of the magnets, which have been determined, are used in equation (18_1) it becomes

$$c_1 + b_1 - b_3 = 3\lambda(1 - 5{\cdot}04 \times 10^{-5}). \qquad (18_2)$$

Neglecting the term $5{\cdot}04 \times 10^{-5}$ makes a difference of less than $0{\cdot}4 \times 10^{-5}$ oersted in the value of H at this observatory.

We may therefore take

$$\lambda = \tfrac{1}{3}(c_1 + b_1 - b_3) \qquad (18_3)$$

and make a correction of 0·4 gamma to the value of H so determined.

$\dfrac{M_0}{H_0} r_0^{-3} = \lambda$ may be obtained by the following observations.

Position I, fig. 1.

Let u_1 be the mean deflection when $\beta = 0°$ and $180°$,

and u_2 the mean deflection when $\beta = \pm 45°$ and $180° \mp 45°$.

Position II, fig. 2.

Let u_3 be the mean deflection when $\beta = 0°$ and $270°$.

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* Phil. Mag., vol. viii, 1904, p. 113.

These observations give $(c_1 + b_1 - b_3)$ and

$$\frac{M_0}{H_0} r_0^{-3} = \lambda = \tfrac{1}{6}(\sin u_1 + \sqrt{2} \sin u_2 + 2 \sin u_3). \tag{18_4}$$

The sin u values in this equation are corrected for temperature, induction, and the changes of H during the observations.

Corrections for Temperature and Variations of H.

The deflection observations are reduced to some fixed temperature t_0 and to a constant value of H, say H_0 the base line value of the H magnetogram.

$$\sin u = \frac{M_0[1 - (a + 3\delta)(t - t_0)]}{r_0^3(H_0 + \varDelta H)} \psi(\beta), \tag{19_1}$$

where a is the temperature coefficient of the magnetic moment, and δ is the temperature coefficient of the bar carrying the deflecting magnet. $\psi(\beta)$ is a function of β given by previous equations.

$$\log \sin u + 0{\cdot}434(a + 3\delta)(t - t_0) + 0{\cdot}434 \frac{\varDelta H}{H_0} = \log \frac{M_0}{H_0} r_0^{-3} \psi(\beta)$$

$$\sin u_0 = \frac{M_0}{H_0} r_0^{-3} \psi(\beta). \tag{19_2}$$

Induction Correction.

Position I, fig. 1. $\beta = 0°$ and $180°$.

$$\sin u_0 = \frac{M_0}{H_0} r_0^{-3} \left(1 - \frac{\mu H}{M} \sin u_0\right) \psi(\beta)_{\beta=0°},$$

where μ is the coefficient of induction.

$$\sin u_0 + \mu \sin u_0 r_0^{-3} \psi(\beta)_{\beta=0} = \frac{M_0}{H_0} r_0^{-3} \psi(\beta)_{\beta=0°}.$$

In the correction term we may take $\psi(\beta)_{\beta=0} = 2$.

Therefore

$$\sin u_0 + 2\mu \sin u_0 r_0^{-3} = \frac{M_0}{H_0} r_0^{-3} \psi(\beta)_{\beta=0°}$$

$$\sin u_1 = \frac{M_0}{H_0} r_0^{-3} \psi(\beta)_{\beta=0°}. \tag{19_3}$$

Position I, fig. 1. $\beta = \pm 45°$ and $180° \mp 45°$.

The correction for induction is

$$-\sqrt{2}\mu \cos(45 + u) r_0^{-3} \quad \text{or} \quad + \sqrt{2}\mu \cos(45 - u) r_0^{-3}$$

according as the north pole of the deflecting magnet lies to the north or south of the line joining the centres of the magnets respectively. u is positive and the mean value for each case.

Let $\sin u_2$ be the mean corrected value, then

$$\sin u_2 = \frac{M_0}{H_0} r_0^{-3} \psi(\beta)_{\beta=45^\circ}. \tag{19$_4$}$$

Position II, fig. 2. $\beta = 90^\circ$ and 270°.

$$\sin u_0 = \frac{M_0}{H_0} r_0^{-3} \left(1 + \mu \frac{H}{M} \sin u_0\right) \psi(\beta)_{\beta=90^\circ},$$

$$\sin u_0 - \mu \sin u_0 r_0^{-3} \psi(\beta)_{\beta=90^\circ} = \frac{M_0}{H_0} r_0^{-3} \psi(\beta)_{\beta=90^\circ}.$$

In the correction term we may take $\psi(\beta)_{\beta=90^\circ} = 1$.

Therefore

$$\sin u_0 - \mu \sin u_0 r_0^{-3} = \frac{M_0}{H_0} r_0^{-3} \psi(\beta)_{\beta=90^\circ},$$

$$\sin u_3 = \frac{M_0}{H_0} r_0^{-3} \psi(\beta)_{\beta=90^\circ}. \tag{19$_5$}$$

Equations (19_3), (19_4), and (19_5) give the corrected $\sin u$ values to be used in equation (18_4).

Oscillation Experiment.

For the oscillation experiment the following relation holds:—

$$M_0 H_0 = \frac{\pi^2 K_0 [1 + (\alpha + 2\delta_1)(t - t_0)]}{T^2 \left(1 + \frac{\mu H}{M}\right)\left(1 + \frac{\Delta H}{H_0}\right)}, \tag{20}$$

where T is the time of a simple vibration, corrected for torsion, arc of swing and clock rate; K_0 the moment of inertia of the magnet at temperature t_0; δ_1 the temperature coefficient of expansion of steel. The other symbols have already been defined.

By a combination of equations (18_4) and (20) both H_0 and M_0 can be determined.

Portable Coil Magnetometer.

This instrument is a Helmholtz-Gaugain coil system with a small magnetic needle suspended at the centre of the system. The magnet-mirror is a platinised quartz cube.

If the axis of the coil system makes an angle α with the magnetic meridian, when the needle is set at right angles to the axis of the coil system by a current i, then $Fi = H \cos \alpha$, where F is the constant of the coil system, *i.e.* the magnetic field intensity at the centre for unit current.

The constant F was determined by comparisons based on the Standard Coil Magnetometer at the Abinger Magnetic Observatory.

The Potentiometer used for measuring the current was standardised at the National Physical Laboratory, Teddington.

La Cour Quartz Horizontal Force Magnetometer (Q.H.M.).

The theory of this instrument was explained and a comparison of the two instruments Nos. 29 and 30 given by Ogg, Gotsman, and Simpson.* Another comparison of these two instruments was made by Simpson and van Wijk † after No. 29 had been used for a long series of field observations, while No. 30 was used for observatory work. This comparison showed that the standard of accuracy is very high and that the instrument is eminently suitable for field surveys and for the comparison of magnetic standards.

The working formula is

$$\log H = C - \log \sin \phi + c_1 t - c_2 H \cos \phi,$$

where ϕ is the deflection of the needle due to torsion, t the temperature, c_1 the temperature coefficient and c_2 the induction coefficient. The constant C and the coefficients c_1 and c_2 were determined at Copenhagen, for Nos. 29 and 30 in June 1937, and for No. 58 in August 1939.

Comparison of the La Cour Magnetometers.

The differences between the base line values, H_0, as determined by the Q.H.M.s Nos. 29, 30, and 58, are given in Table I in gamma units (1 gamma unit $= 10^{-5}$ oersted).

During the years 1937–1940 the observations were made at the Magnetic Observatory, Cape Town, where the La Cour variometer had a sensitivity of about 5·23 γ/mm., and during the years 1941–1942 at the Magnetic Observatory, Hermanus, where the Askania variometer had a sensitivity of about 2·44 γ/mm. in 1941 and 2·31 γ/mm. in 1942.

One set of observations with these instruments consists, on the average, of five separate determinations.

For the last three years the differences between the determinations by Q.H.M.$_{30}$ and Q.H.M.$_{29}$ are within the error of observation. There has been a gradual change of the differences between the determinations by Q.H.M.$_{30}$ and Q.H.M.$_{58}$ of about 1 gamma per year.

Comparison of the C.I.W.$_{17}$ Magnetometer with Q.H.M.$_{30}$ and Q.H.M.$_{58}$.

During the year 1939 a considerable number of determinations were made with the C.I.W. magnetometer, but in later years only a few determinations were made because observers had confidence in the use of the Q.H.M. instruments for base line measurements. Two determinations by C.I.W.$_{17}$ is called a set (Table II).

* Trans. Roy. Soc. S. Afr., vol. xxvi, 1938, p. 395. † *Ibid.*, vol. xxvii, 1939, p. 223.

TABLE I.

Period.	Sets of Obs.	$H_0(Q.H.M._{30}) - H_0(Q.H.M._{29})$.	Period.	Sets of Obs.	$H_0(Q.H.M._{30}) - H_0(Q.H.M._{58})$.
		γ			γ
22/9/37 to 6/6/38	8	+1·8	5/9/39 to 9/11/39	4	+1·3
11/5/38 to 29/7/38	4	+0·9	12/6/41 to 5/11/41	2	−0·3
11/4/39 to 24/4/39	4	+0·7	20/10/42 to 26/10/42	4	−2·1
19/9/39 to 9/11/39	5	+0·4			
31/7/40	1	+0·3			
12/6/41 to 5/11/41	2	−0·1			
20/10/42 to 26/10/42	3	+0·1			

TABLE II.

Year.	Sets of Obs.		$H_0(Q.H.M._{30}) - H_0(C.I.W._{17})$.	Year.	Sets of Obs.		$H_0(Q.H.M._{58}) - H_0(C.I.W._{17})$.
	Q.H.M.	C.I.W.	γ		Q.H.M.	C.I.W.	γ
1939	34	24	−1·0	1941	35	9	+3·6
1940	60	7	+0·3	1942	46	8	+4·4
1941			+3·3 *				
1942			+2·3 *				

* Derived from Tables I and II.

COMPARISON OF THE COIL MAGNETOMETER WITH $Q.H.M._{58}$ AND $C.I.W._{17}$.

The comparison of the Coil Magnetometer was made with the $Q.H.M._{58}$, because readings can be taken so rapidly with the Q.H.M. instruments, and then the comparison with $C.I.W._{17}$ derived from Table II. A set of observations means about the same number of determinations with each instrument.

TABLE III.

Year.	Sets of Obs.	$H_0(Q.H.M._{58})$ $-H_0$(Coil Mag.).	$H_0(C.I.W._{17})$ $-H_0$(Coil Mag.).
		γ	γ
1941	6	+7·3	+3·7 *
1942	6	+8·6	+4·2 *

* Derived from Table II.

The constant of the coil was determined at Abinger when the magnetic needle was attached to a float pivoted on a jewel bearing.* We found that this method of suspension was not sufficiently reliable for standard measurements. This pivot suspension was discarded for a fibre suspension, which also proved unsatisfactory when the float was in liquid. The above measurements were taken with the float hanging in air, producing a constant tension on the fibre.

COMPARISON OF THE SCHMIDT STANDARD MAGNETOMETER WITH $Q.H.M._{58}$ AND $C.I.W._{17}$.

As the magnets belonging to the Schmidt Magnetometer were not available, the magnets of the Askania Portable Magnetometer were used for this comparison. The moments of inertia and the coefficients of induction, which were determined at this observatory in 1941 and 1942, and the temperature coefficients of the magnetic moments, which were determined at Niemegk Observatory in 1937, have been used in the calculations.

$\frac{H_0}{M_0}$ has been found by equation (18_3) and the correction $+0·4\ \gamma$ applied to value of H_0 derived from the deflection and oscillation experiments.

As a determination of H with the Schmidt Magnetometer means the measurement of a large number of deflection angles, also periods of oscil-

TABLE IV.

Sets of Obs.	Magnet.	$H_0(Q.H.M._{58})$ $-H_0$(Schmidt Mag.).	$H_0(C.I.W._{17})$ $-H_0$(Schmidt Mag.).
		γ	γ
5	I	+5·3	+1·1
6	II	+8·5	+4·4

* Geomagnetism, Chapman and Bartels, vol. i, p. 43.

lations, and involves considerable calculation, a set of observations denotes a single determination compared with 5 determinations with the Q.H.M. With Magnet I one set, and with Magnet II two sets were made in 1941, and the others in 1942.

COMPARISON OF THE MAGNETIC HORIZONTAL INTENSITY DETERMINED WITH THE MAGNETOMETERS OF THE MAGNETIC OBSERVATORY, HERMANUS, WITH THE INTERNATIONAL MAGNETIC STANDARD (I.M.S.).

The constants of the C.I.W.$_{17}$ magnetometer were determined at the Department of Terrestrial Magnetism, Carnegie Institution, Washington, in July 1932, and the correction to International Magnetic Standard (C.I.W. Magnetometer No. 3) was then $-0{\cdot}00001$H.

TABLE V.

Corrections to International Magnetic Standard of Horizontal Intensity obtained with various Magnetometers.

Date.	Magnetometer.	Observatory.	ΔH.		Magnetometer used for the Comparison.
			γ		
1932	C.I.W.$_{17}$	Washington	..	$-0{\cdot}00001$H	Direct
1933	Schuster-Smith	Agincourt	$-4{\cdot}8$	$-0{\cdot}00031$H	C.I.W.$_{16}$
1935	Schuster-Smith	Abinger	$-1{\cdot}2$	$-0{\cdot}00007$H	C.I.W.$_{18}$
1935	Schmidt	Niemegk	$-3{\cdot}5$	$-0{\cdot}00019$H	C.I.W.$_{18}$
1941	Q.H.M.$_{30}$	Hermanus	$-3{\cdot}3$	$-0{\cdot}00023$H	C.I.W.$_{17}$
1941	Q.H.M.$_{29}$	..	$-3{\cdot}2$	$-0{\cdot}00022$H	
1941	Q.H.M.$_{58}$	..	$-3{\cdot}6$	$-0{\cdot}00025$H	
1942	Q.H.M.$_{30}$	..	$-2{\cdot}3$	$-0{\cdot}00016$H	
1942	Q.H.M.$_{29}$	..	$-2{\cdot}4$	$-0{\cdot}00017$H	
1942	Q.H.M.$_{58}$	..	$-4{\cdot}4$	$-0{\cdot}00031$H	
1941	Coil Magnetometer	..	$+3{\cdot}7$	$+0{\cdot}00026$H	Q.H.M.$_{58}$ and C.I.W.$_{17}$
1942	Coil Magnetometer	..	$+4{\cdot}2$	$+0{\cdot}00029$H	
1942	Schmidt Magnetometer	..	$+3{\cdot}0$	$+0{\cdot}00021$H	

The moments of inertia of the magnets were redetermined at Cape Town in December 1938, in February, June, and July 1939; at Hermanus in May and October 1941 and March 1942. The induction coefficient of the magnetic moment was checked in 1942.

It has been assumed that with C.I.W.$_{17}$, when allowance is made for the change of moment of inertia, the correction of H to I.M.S. is the same in 1942 as in 1932.

"The results of the International Comparison of Magnetic Horizontal

Intensity with Sine Galvanometer 1" of the Department of Terrestrial Magnetism of the Carnegie Institution, Washington,* enable us to show also the comparison of the standard magnetometers at Abinger and Niemegk with International Magnetic Standard.

The results of this comparison of Horizontal Intensity Magnetometers show that the Q.H.M. instruments give consistent and reliable values of the horizontal intensity of the earth's magnetic field, and that the rate of change is of the order of 1 γ per year compared with C.I.W.$_{17}$. The suitability of these instruments for field observations has been shown by Simpson and van Wijk † and Ogg.‡ The results also show that the standardisation at Copenhagen gives values which are in close agreement with those derived with the standard magnetometers at Washington, Abinger, and Niemegk.

In view of our experience with Q.H.M. instruments it is difficult to understand why the mean difference ΔH (K-standard − Q.H.M.) for the three Q.H.M.s Nos. 12, 17, and 18 should be $+16{\cdot}6\,\gamma = 0{\cdot}00059$H at Kakioka Magnetic Observatory.§

The rapidity with which horizontal intensity measurements can be made with the Q.H.M. magnetometers make them particularly suitable for determining the base line values of magnetograms, also for the comparison of magnetic standards and for field observations.

Magnetic Observatory,
Hermanus, C.P.,
South Africa,
17*th November* 1942.

* Trans. of the Edinburgh Meeting of the Assoc. of Terr. Mag. and Atmos. Elec., 1936, p. 248.

† Trans. Roy. Soc. S. Afr., vol. xxvii, p. 223, 1939.

‡ *Ibid.*, vol. xxix, p. 261, 1942.

§ Trans. of the Edinburgh Meeting of the Assoc. of Terr. Mag. and Atmos. Elec., 1936, p. 260.

AFRICAN SUICIDES IN THE BAMENDA DIVISION, BRITISH CAMEROONS.

By M. D. W. Jeffreys, M.A.(Oxon.), Ph.D.(London).

(Read August 19, 1942.)

The literature on "Suicide" among the indigenous peoples of Africa is scanty and no statistics exist by which the rate per thousand of the population may be estimated. The following notes on all reported cases of suicide, during four years in the Bamenda Division, are therefore put on record. This Division forms part of the Mandated Territory of the Cameroons and has an area about the size of Wales, *i.e.* 6934 square miles, a native population of some 281,000 natives, and less than 200 miles of motorable roads. There are no European settlers, and the total European population consists of nine Government officials with four wives and three children, ten Missionaries with two wives and four children, and six nuns—in all 38 persons.

During four complete years, over which I have notes, there were in all 48 suicides. The lowest was 11 in 1936 and 13 in 1939. All were adults, and the sex ratio of 18 females to 30 males is close to the two-to-one ratio found for the sexes elsewhere; thus, the British Medical Journal, commenting on the latest population statistics for England and Wales, said: ". . . and it is worth noting that twice as many men as women committed suicide (in 1938)—3558 against 1758 (1)."

The method of despatch was recorded in 37 out of the 48 instances and is shown in Table (A).

TABLE "A."

	Hanging.	Stabbing.	Poison.	Fire.
Men . . .	20	2	..	1
Women . .	11	2	1	..

The instances are not sufficient to say that the native female, like her European sister, shows a preference for a mode of death that avoids the spilling of blood or personal disfigurement. Nevertheless out of 14 females

whose mode of death is known only 2 were by stabbing, and in this connection the following is of interest. "The usual (and with woman the only) method of committing suicide is by hanging, but sometimes a man will fall forward on his spear or stab himself in the stomach" (2).

In Europe, a seasonal suicide rate exists; the rate is higher in summer than in winter. In Bamenda, where the seasonal temperature variation is small, no such conclusion can be drawn. The warmest months are February to April. On the other hand, if the total suicides in the four years are shown month by month and grouped according to each quarter, then the harvest quarter has the highest rate, thus:—

TABLE "B."

January .	1	April .	4	July .	5	October .	4
February .	5	May .	2	August .	4	November	6
March .	2	June .	5	September	2	December	8
	8		11		11		18

There is a possible explanation for the distribution of suicides, namely the failure of an individual's crop, through sickness preventing attention to it while it was growing, but the exciting cause will generally be found to be quite a trivial matter.

To gain a rough idea of the suicide rate per million of the population the following data are supplied. There are twenty-three tribes in the

TABLE "C."

Rain Forest Tribes.

Tribe.	Population.	No. of suicides.				Total.	Rate per million p.a.
		1936.	1937.	1938.	1939.		
Moghamo .	14,168	3	..	4	3	10	178
Menemo . .	13,641	2	..	..	1	3	55
Ngwaw . .	6,813	..	2	..	..	2	72
Ngi . .	14,634	2	2	2	..	6	102
Mbembe . .	10,361	..	1	1	..	2	48
Beba-Befang .	9,517	..	..	..	2	2	53
Totals . .	69,134	7	5	7	6	25	90

division; not all have provided suicides. For taxation purposes the name of each adult male is recorded in a Nominal Roll book. From the totals of these books the population is estimated on the following percentages: 28 per cent. adult males; 33 per cent. adult females; 39 per cent. children. The estimated total population then works out at about 281,000 persons. In the same way, the total population of each tribe is ascertained. I know that the figures of suicides are too few, and the period too short, for any reliable conclusions to be reached, but, such as they are, they may serve as indicators. Tables "C" and "D" show the distribution of suicides according to tribes and also according to the tribe being situated in Rain Forest or in open Grassland.

TABLE "D."

Grassland Tribes.

Tribe.	Population.	No. of suicides.				Total.	Rate per million p.a.
		1936.	1937.	1938.	1939.		
Nkom	14,168	1	2	..	1	4	71
Bali	12,394	1	..	3	..	4	80
Ndop	28,015	1	2	..	1	4	36
Nsaw	26,863	..	1	..	..	1	9
Ngemba	15,725	1	1	..	3	5	80
Bufu	21,719	..	1	1	..	2	24
Misaje	6,042	..	..	1	..	1	42
Aghem	6,248	..	..	..	1	1	40
Mbem	12,532	..	..	..	1	1	20
Totals	143,706	4	7	5	7	23	40

These suicide rates may be profitably compared with those from other countries, and Table "E" gives such rates.

TABLE "E"

Chile (1923)	24	per million living.
Spain (1923)	37	,,
Netherlands (1925)	62	,,
Iceland (1925)	63	,,
Colombia (1920)	84	,,
Italy (1925)	92	,,
Union of South Africa (Whites only, 1923)	113	,,
England and Wales (1926)	114	,,
Australia (1926)	118	,,
United States (1926)	128	,,

TABLE "E"—*continued.*

New Zealand (1925)	130	per million living.
Belgium (1922)	131	"
Denmark (1925)	136	"
Uruguay (1923)	136	"
France (1925)	200	"
Austria (1922)	228	"
Germany (1925)	243	"
Hungary (1922)	275	" (3)

In Tables "C" and "D" the tribes are grouped geographically, according as they are Forest or Grassland, and the tables show that the suicide rate is more than twice as high among the Forest tribes as among the Grassland peoples. The Forest rate compares with that for Italy, while that for the Grassland is close to the Spanish rate. The high rate among the Moghamo occurs in a tribe through which a main motor road runs. Part of the tribe is on the Grassland fringe. The next highest rate occurs in a tribe well off the beaten track and seldom visited. It also lives on the Grassland fringe.

It is difficult to account for the higher suicide rate among the Forest tribes. I have worked for years among the Ibibio, an essentially Forest tribe, and, though I have no figures, I know that the suicide rate was very much lower. My knowledge is based on the following facts. The Ibibio number over 700,000, yet the number of suicides reported per annum was less than the suicides here. In fact, suicide was comparatively rare and did not compare with an average of 60 murders a year which was the Ibibio rate for a long time.

Of the tribes listed, the Ngi and the Ngwaw are the least sophisticated and the least in touch with civilizing and administrative centres.

The trifling causes that were the occasion of the suicides may be gauged from the following information.

Nigerian law requires an inquest to be held on each death by violence, and extracts from the minutes of evidence are given below to show the trifling causes which have prompted individuals to destroy themselves. In the case of the female, Eduga Nkpo, of Bassa town, Ngwaw tribe, who died on the 18th of July 1937, her husband's evidence was: "I had two wives, Eduga Nkpo, who was my first wife and who had four children by me, one of whom is living, and Sembe, who is my second wife, who has two children by me. About three weeks ago, I came home after cutting palm kernels to find my sister, Amange, of Bakpa, on a visit to me. She had brought me some food. I called my wives and children to come and eat. Afterwards my first wife brought some food prepared by her for me. On lifting the lid of the pot I found a bufferfly in the soup. I felt disgusted

and told her to give this soup to the children. My wife became annoyed and threw the food away, outside. My second wife, Sembe, and my daughter, Adia, were present. I saw this, but kept quiet, nevertheless there was a row afterwards. In the evening I went to bed. My wife followed me with her child between us. Towards daybreak she went out; as usual I did not take it otherwise than that she went to ease herself. I went to sleep again. I heard no noise and so slept on. In the morning when I woke up she was not on the bed and I thought she had gone to the latrine. To my surprise when I went outside I found her hanging on a tree opposite my house and about twenty footsteps away. I shouted and Sembe and other people came out. I loosed her off the rope and laid her on the ground. I drummed to her people and they came. They wanted to bury her, but I refused to allow them to do so and said that the matter must be reported to the Court and I was sent to Bamenda. My wife has done bad to me, to leave me a widower. She was the best of the two. I think it was the row about the food she had cooked that waked up her heart to hang herself. It is a habit in her family. Her grandfather and her own father hanged themselves. She has left a child two years old. No one killed my wife. Mbe, his X mark."

Here a little chagrin, a little petulance, perhaps a little shame, is all that appears as both the occasion and the cause for the suicide.

A man, Inchianwu, stabbed himself either in a fit of rage or shame. The evidence at the inquest ran as follows: "Akunchia Ndembi duly sworn states, I am the quarter head of Akumbechia, in Ebung town, Ngi. About four days ago when I was returning from the chief of Ebang's place, my son told me that Ichianwu, of Afet, had stolen two of my goats. I sent Abidembe and two others to find out and, if the reports were true, to ask Ichianwu to return my goats by them. After some time, on the same day, Abidembe came to me and said they had not seen the goats and that Ichianwu denied the theft. He also stated that Ichianwu became greatly enraged and threatened them with a spear and that when they were running off, he, Abidembe, heard Ambebi, wife of Ichianwu, shouting that her husband had stabbed himself with a knife. . . . Four days after this Ichianwu died. Akumichia Ndembu, his X Mark."

Two suicides were of the nature of a suicide pact. Two young men hanged themselves on Christmas Day for a puerile reason. The two had been accustomed to have their food prepared by their mother. She died. Their two penile half-sisters, who were married, graciously carried on the duties of the dead woman. The two young men quarrelled with their half-sisters over their food which was either not to their liking—not as mother used to cook it—or else was at times not cooked at all, but was delivered at their hut in the raw state and left for them to cook. On

Christmas morning, 1939, these two men took a calabash of palm wine to a friend's compound and spent the day drinking. During their absence their two half-sisters took a present of food and left it at the deceaseds' hut. Part of the food was cooked and part was not. The next morning the food was found scattered about the floor of the hut and the two men hanging from the same tree within a few feet of each other.

It appears that returning from their carousal they were disappointed to find that even on Christmas Day they were expected to prepare their own food, and in a state of chagrin had kicked the food about and had then hanged themselves. There was no duty or obligation on the two married half-sisters to feed or to look after their two half-brothers.

An illegitimate son of the paramount chief of the Nsaw tribe was imprisoned for stealing money from the tribal treasury. A child of the miscreant died shortly after his father's arrest. The head of this branch of the royal family remarked that the disgrace brought on that branch had angered the ancestral spirits who had therefore caused the death of the child and that he, himself, could no longer live under this disgrace. He went away and hanged himself.

Mary Kingsley noted that frustration and suicides were intimately connected in the native social organisation and also drew attention to the high, emotional content of the negro. Thus, when sleeping sickness was destroying the people of the Congo and frustrating the purpose of life, she wrote: " . . . the two West African native diseases most interesting to the European on account of their strangeness, are the malignant melancholy and the sleeping sickness, and strangely enough both these diseases seem to have their head centre in one region—the lower Congo. Regarding the first-named I am still collecting information, for I cannot tell whether the malignant melancholy of the lower Congo is one and the same with the hystero-hypochondria, the home-sickness of the true negro. In the lower Congo I was informed that this malignant melancholy had the native name, signifying 'throwing backwards,' from its being the habit of the afflicted to throw themselves backwards into water when they attempted a drowning form of suicide. They do not confine themselves to drowning, but are equally given to hanging" (4).

Professor de Jastrebski holds much the same point of view. He considers that lack of interest in life itself is the most potent factor in causing suicide, but lack of interest in life follows frustration of emotional expression; in other words, lack of interest in life is a symptom, not a cause of, suicide. He writes: "To the theory that nervous strain is one of the prime causes which lead to self-destruction they (the decreased suicide rates in 1914–18) give a complete and emphatic contradiction—while, on the other hand, they furnish the most weighty volume of indirect

evidence that, lack of interest in life itself should be regarded as one, if not *the*, most important of the factors at work" (3).

These observations indicate no divergence from the causes that obtain among, and the methods used by, the European in committing suicide, and it must be assumed that the fundamental psychological make-up of the local native differs in nowise from his European confrère.

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LE PALÉOLITHIQUE AU CONGO BELGE D'APRÈS LES RECHERCHES DU DOCTEUR CABU.

Par l'Abbé Henri Breuil.

(Read March 17, 1943.)

Les industries paléolithiques congolaises viennent de plusieurs régions géographiques, et l'on doit les examiner successivement, dans leur ordre stratigraphique pour chaque région, en essayant ensuite d'en raccorder les divers ensembles.

I. Haut Pays de Piemont a la Limite des Bassins du Congo et du Zambese.

I. *Région orientale.*—Deux pièces caractéristiques de TENGO-MUTUMBA témoignent d'une taille élémentaire, de deux ages pour l'une, se rapprochant de la PEBBLE CULTURE de l'Uganda et du KAFUAN du Kenya, et également des séries, contenant plus d'éclats que de galets taillés, des très anciens graviers du Vaal (Vereeniging, terrasse de 100′; Windsorton, terrasse entre 45′ et 250′). Je ne suis pas étonné que d'aussi anciennes industries proviennent de graviers de haut plateau appartenant à des cours d'eau différents du réseau hydrographique actuel.

L'objet découvert dans l'île artificielle de KAWA, à 90 m. au dessus du pied de la grande chute de la Kalule-Sud, et extrêmement roulé, me parait abbevillien; il est antérieur au gravier qui le contenait.

A. *Gisement de la KAMOA.*

Vers 1050 m. d'altitude, c'est-à-dire à 60 m. plus bas que le plateau où le Lualaba (Congo) et ses affluents prennent leur source. Les graviers quaternaires y reposent sur la tillite glaciaire d'âge prékundelungu. On peut distinguer trois séries d'âges successifs dans les pièces qui m'ont été soumises.

(a) *Série plus ancienne.*—4 pièces, toutes façonnées, à partir d'éclats clactoniens, en coups-de-poing de taille *abbevillienne.* Ces types sont entièrement semblables: 1° au Stellenbosch I du gravier ancien le plus bas de Vereeniging sur le Vaal, que je considère comme notablement plus vieux que les divers gros graviers non décomposés à Stellenbosch II–V du

fond de cette vallée. 2° aux séries extrêmement anciennes découvertes près Casablanca, sur la plage sicilienne et sous la dune consolidée pré-milazzienne et la plage milazzienne d'Abderrhaman, par R. Neuville et A. Ruhlman. Ces pièces sont, à la Kamoa, d'un roulis accentué et d'une, altération très profonde du grès polymorphe rouge dont elles sont faites.

(b) *Roulis très faible.*—Cette série, comprenant des limandes ovales et de nombreux hachereaux (cleavers), rappellent l'Acheuléen ancien de la Somme (de I à III) et surtout le *Stellenbosch moyen* des graviers du fond de la vallée du Vaal. Comme dans celui-ci, les bifaces sont faits par retaille d'éclats latéraux ou longitudinaux.

(c) *Séries non roulées ou très peu.*—Types bifaces et unifaces, souvent aussi sur éclats en forme de limandes lancéolées, ellipsoïdes, de travail plus évolué dans les pièces plus poussées.

Elles sont à rapprocher du Stellenbosch plus évolué des graviers de fond de vallée du Vaal et rappellent l'Acheuléen supérieur (IV et V) de la Somme.

B. *Eboulis des graviers de Luabo.*

La seule pièce qui m'est soumise, non roulée, et de patine blanchâtre et profonde, malgré son caractère massif de coup-de-poing piriforme très court, témoigne d'une taille large et régulière et de retailles secondaires assez soignées (travail au bois) supposant une phase acheuléenne très avancée.

C. *Argile sableuse kaolineuse de Ruashi* (*Elisabethville*).

Amande biface très régulière, mince, sur éclat probablement à tendance lancéolée, de caractère acheuléen très évolué (cfr Stellenbosch V ou Fauresmith d'Afrique du Sud). N'est pas suffisante, pas plus que la précédente, pour en dire d'avantage.

D.—Des pièces sporadiques analogues aux ensembles précédents ont été dérivées secondairement dans les graviers de base des terrasses du Kasai, de la Bushimaie, du Lubilash et du Sankuru, souvent très défigurées par le roulis.

C'est le cas d'uncertain nombre d'éclats de technique clactonienne, l'un de Lupweji, d'autres de Mutwaya.

II. Plateaux du Kasai.

Vers l'altitude de 800 m., c'est-à-dire 150 m. plus bas que les graviers de la Kamoa, dont elle est séparée par une vaste pénéplaine que des mouvements tectoniques ont rompue en quatre gradins franchis en rapides par les cours d'eau, se trouve la terrasse supérieure du Kasai, d'une épaisseur de 60 à 90 m. reposant sur les roches en place ou des sables blancs grisâtres

compacts stériles. Plus bas, vers l'altitude de 700 m., se trouve une moyenne terrasse, avec, de 2 à 4 m. plus bas, une basse terrasse ne dominant le thalweg actuel que de 2 m. environ.

I. *Haute terrasse du Kasai.*—Elle est constituée d'une série de dépôts:

(1) Graviers et boulders fluviatiles de base;

(2) Sables fluviatiles argileux grisâtres qui sont un niveau de sources;

(3) Argile sableuse rouge non stratifiée, d'origine éolienne, souvent recouverte, en région schisteuse ou à dolérite, par un niveau de ferricrète;

(4) Sur celui-ci, des sables éoliens récents se sont épandus.

A. *Industries des graviers.*

Série I. Assez émoussées par le roulis.—Des trois pièces qui me sont soumises, deux de Bibanga sont de petits bifaces ovales, de taille rappelant l'Acheuléen, terminées à un bout en ciseau. Leur dimension est inférieure à celle de l'Acheuléen et du Stellenbosch. La troisième, de Milalayi, est un ciseau biface fusiforme à talon pointu et taillant en arc de cercle, recto très convexe et verso assez plat.

On entre là dans une ligne d'évolution proprement centre et est-africaine, le *Kalinien*, différente de celle de l'Afrique du Nord et du Sud, bien que, dans les industries paralèlles de ces régions, l'on pourra (au contraire de l'Europe) trouver, dans le Stellenbosch final et le Fauresmith, des pièces isolées comparables.

Série II. Peu usées par le roulis.—Site de Tshikapa; trois pièces examinées, l'une foliacée, lancéolée épaisse, à taille régulière, soignée, rappelant un biface Fauresmith (cfr Micoquien d'Europe, ou Moustérien de tradition acheuléenne). La seconde est foliacée ovale-oblongue, à talon de cortex, tranchants latéraux convexes et à bout rond mais employé comme ciseau. La troisième, gouge arrondie, plus allongée, est à recto assez bombé.

Des pièces analogues viennent de *Mikalayi*: pointe foliacée épaisse à talon de cortex, dissymétrique dans les deux sens; de Bakwakanga: biface elliptique dissymétrique encore, à bout en ogive utilisé en ciseau-gouge.

Diverses pièces accessoires témoignent de la technique de débitage levalloiso-moustérienne à cette époque, en usage courant dès le Fauresmith sud-africain: disque moustéroïde circulaire de DONGE, éclats moustéroïdes à plan de frappe préparé à facettes, dérivés dans la basse terrasse de Lusambo, sous 4 m. d'alluvion, éboulis de Luabo, etc.

B. *Base de sables gris argileux; pièces non roulées*, en surface des graviers, dans des sables argileux sous-jacents à 60–90 m. d'argiles sableuses rouges non stratifiées.

Une telle épaisseur de dépôts fluviatiles, puis éoliens superposés avec la croute de ferricrète qui termine cette série de sédiments quaternaires, et que recouvre du sable soufflé récent, est identique à ce que l'on constate dans les vallées et vallons latéraux au Vaal et dans la Riet-River. L'industrie que l'on rencontre à ce niveau, dans ces derniers sites, appartient au Fauresmith, où la tradition des bifaces acheuléens s'associe à une technique de débitage levalloisienne assez avancée; on l'appellerait en France Levalloisien ou Moustérien de tradition acheuléenne. Ici, l'évolution particulière ébauchée dès le niveau précédent, s'accentue en une industrie qui mérite le nom spécial de Kalinien malgré ses liens avec le Fauresmith d'une part, et le Levalloisien d'autre part.

Les séries qui m'ont été soumises sont assez abondantes pour en permettre une étude sérieuse.

J'y note, au point de vue technique, plusieurs nucléi moustéroïdes discoïdes, à plan de frappe préparé à facettes, de Mikalayi et un éclat-pointe du même site, ayant les mêmes caractéristiques.

La tradition Stellenbosch se poursuit comme dans le Fauresmith du Vaal, ainsi que l'établit un éclat latéral à plan de frappe préparé à facettes; c'est un hâchereau de dimension réduite, de technique "Victoria-West."

Quelques éclats ont été modifiés par des retouches: éclats épais foliacés de Kankulu-Bibanga à deux bords retouchés et pointes émoussées; large éclat ovale-oblong de Mikalayi, sorte de limande uniface à bouts arrondis; type pas rare dans le Fauresmith.

Les autres pièces, bien plus modifiées, où les surfaces primitives de l'éclat original ont généralement disparu, sont des outils ou des armes.

Outils.

A noter d'abord deux pièces de Bockland (Mikalayi) et de Kankulu (Bibanga) en forme de pics fusiformes, façonnés d'éclats larges à bulbe d'extrémité; ils ont été réalisés par retaille du plan d'éclatement sur le tiers de pointe, le reste du verso étant laissé intact.

En revanche, le recto, très bombé, est retaillé et les bords sont, dans le plus fort (20 cm.), dentelés.

Les pics-ciseaux, rares en Afrique du Sud, présents en Rhodésie, abondent, mais plus forts, dans les industries de l'Uganda et se retrouvent aussi dans le Nanyukien du Kenya, associés aux bifaces cordiformes du Fauresmith et au débitage levalloisien évolué. Ils ressemblent, en Europe, à des formes qu'on ne voit se multiplier qu'au début du Néolithique, ce qui a induit en erreur ou préjugé les préhistoriens sur l'âge des pièces africaines. Il y a cependant, dans la région de Tebessa, Sud-Constantinois, quelques pics en silex de ce genre dans des milieux acheuléens locaux et un grand nombre dans les lieux

où ce silex était extrait par les hommes contemporains. Monsieur Reygasse a donné un nom à ce facies d'exploitation de l'Acheuléen d'Algérie.

Beaucoup d'autres types congolais sont du même genre de travail: imparfaitement bifaces ou entièrement bifaces, et alors souvent à recto très surélevé et verso bien plus plat. fréquemment à un bord soigné et à fil bien alligné et l'autre sinueux et grossièrement taillé en quelques coups (au cas où l'éclat original était à bulbe latéral. Il est fréquent que la base garde du cortex et soit un peu épaisse; l'autre extrémité, parfois les deux, est façonnée le plus souvent en ciseau à taillant arrondi ou anguleux, témoignant, par ses brêches de travail ou ses réparations, d'un usage comme gouge ou ciseau. Le bord plus soigné, généralement abrupt, à tranchant souvent faiblement convexe, est fréquemment profondément dentelé; l'objet servait par là à la façon d'une plane ou d'une scie-tiers-point. Ce sont tous des outils de travailleurs de bois, souvent complexes, à la façon des outils "américains" de nos jours. Leurs proportions varient de types assez régulièrement ovoïdes, tronqués ou non par le biseau transversal ou arrondi, à des types fusiformes réguliers, s'évasant légèrement parfois à la base ou à la pointe; exceptionnellement en ce cas, on atteint la forme d'une hachette taillée oblongue protonéolithique européenne. Mais nous ne sommes pas en Europe; des milieux Stellenbosch évolués des graviers des fonds de vallées du Vaal donnent, en dimensions plus fortes, déjà quelques types analogues, et ils sont moins exceptionnels et plus proches de la dimension congolaise dans les milieux du Fauresmith sud-africain. Leur âge quaternaire moyen n'est donc pas douteux dans ces pays, comme dans l'East Africa.

Les pièces examinées venaient de Bakwakanga (Bibanga), de Kankulu (Bibanga), de Mikalayi, Lupweji, Tshikapa (Forminière) etc.

Armes.

Les mêmes localités, dans le même niveau archéologique, ont livré des armes, destinées à blesser par leur extrémité pointue. Elles évoquent, pour un européen, le souvenir des "ébauches" de feuille de laurier un peu épaisses de Laugerie-Haute, par exemple. J'en ai vu cinq de Mikalayi et de Bibanga. L'une, peut-être inachevée, rappelle un biface acheuléen mince, fusiforme large, à surface naturelle à la base pointue, taille biface très plate, sans retouche secondaire (Mikalayi). Une autre est un petit biface lancéolé, d'aspect micoquien, mais à talon peu épais. Une feuille de laurier allongée montre un talon de cortex; des très faibles concavités symétriques à son tiers de base évoquent un emmanchement (Bibanga). Une autre feuille de laurier fusiforme, un peu fruste a un seul tranchant à retouche soignée (couteau ?- Mikalayi); une dernière fusiforme, après accident, a eu la pointe refaite en perçoir.

Ces divers objets constituent une sorte de transition entre des types de tradition acheuléenne évoluée (Fauresmith Micoque) et des formes solutroïdes qui, en Afrique du Sud, appartiennent à divers stades du Middle Stone Age, pour aboutir à la civilisation Moustérosolutréenne de Still-Bay.

C. *Industries des sables argileux rouges sub-aériens.*

Ce niveau très épais (60–90 m.) succède aux sables argileux qui précèdent; il est d'une grande richesse industrielle; les formes précédentes se poursuivent: ciseaux-gouges bifaces, oscillant entre des types foliacés courts un peu larges, à talon épais ou arrondi; et d'autres fusiformes allongés à talon pointu.

Mais certaines pièces sont plus élaborées: baguettes longues et étroites; tantôt à section lenticulaire et deux faces également convexes; tantôt à verso plat et recto bombé, à côtés épannelés verticalement; l'extrémité utile (parfois les deux) est en tranchant convexe parabolique, elle présente souvent des traces d'usure et de réparation. Dans quelques pièces, on observe nettement la retouche par pression sur les bords, et aussi une différenciation entre les deux tiers de pointe, plus soigneusement taillés et seuls bien retouchés, et le tiers de base, assez grossièrement façonné.

Quelques pièces pointues sont trop fragiles pour des outils, mais trop lourdes pour avoir armé des armes de jet; une seule, amincie à la base, a pu servir de pointe d'épieu.

Mais la tradition "acheuléenne" se maintient, comme le montre une amande oblongue ayant l'aspect d'un petit biface Fauresmith, primitivement lancéolé, mais qu'une réparation de la pointe a raccourci. Tout cela n'est que le développement normal de l'industrie Kalinienne des deux niveaux antérieurs de la même terrasse.

III. Basse Terrasse Superieure.

Son sommet est à une centaine de mètres en contrebas de celui de la haute terrasse précédente; elle est aussi constituée de gros graviers de base, surmontés de niveaux de sables fluviatiles, recouverts eux-mêmes d'argile sableuse rouge. Nous examinerons successivement le contenu de ces divers niveaux.

A. *Industries des graviers de la basse terrasse supérieure.*

Nous en distinguerons deux séries d'usure différente.

Série a. Plus usée.—Ces objets me paraissent dérivés de la terrasse précédente, les uns, de patine noire ou grisâtre, de la base de l'argile sableuse grise, d'où sortent des sources, d'autres de la base des argiles rouges, ont

une patine rousse; d'autres à patine blanche brillante, du sommet de la même couche.

On y retrouve naturellement les mêmes types déjà rencontrés *in situ* dans ces assises; leurs points de trouvaille sont Lupemba et Bendai.

Série b. Objets peu usés, mais assez lustrés.—A ce niveau apparaissent de véritables *poignards*, caractéristiques de l'industrie *DJOKOCIENNE*, que l'on n'a pas rencontrée dans les séries de la haute terrasse. Il en est de moins élaborés, comme une pointe foliacée allongée, faite d'un grand éclat long, conservant encore les plans de frappe et d'éclatement, mais à bulbe enlevé par une facette transversale. La pointe ogivale a été réparée. Tout le bord gauche du verso présente des traces d'avivages réitérés témoignant d'un usage latéral. La retouche, plutôt courte mais très large, rappelle la technique solutréenne incipiente. Un tel objet ne serait pas dépareillé dans des milieux sud-africains de transition entre le Fauresmith et le Middle Stone Age.

Mais les pièces caractéristiques sont autrement parfaites: ce sont des objets très allongés, généralement fusiformes tronqués à la base, variant de 12 à 32 cm. de long; faits sur éclats longs, leur section est fréquemment trièdre, avec arête médiane dorsale entre les retailles remontant des deux bords.

L'un de ceux-ci n'est fréquemment taillé qu'à grands éclats; la taille est ordinairement plus soignée dans la moitié ou les deux tiers de pointe; ceux-ci sont en outre soigneusement retouchés, tandis que la retouche ne s'étend pas à la partie de base.

Celle-ci est évidemment une poignée, généralement plus épaisse que l'autre, et séparée fréquemment de celle-ci par une très légère saillie latérale ou une concavité de face.

Leur travail est remarquablement habile, et ce sont des chefs d'oeuvre de l'âge de la pierre paléolithique congolais.

Les points de trouvaille sont Tshikapa (Forminière), Lupemba, Bendai sur Kasai.

B. *Sur les graviers à la base des sables fluviatiles.*

Série a.—L'industrie djokocienne s'y retrouve abondamment; une partie des objets, par leur patine noirâtre, paraissent encore dérivés du niveau des sources, base de la couche sableuse argileuse grise de la haute terrasse. Ce sont des ciseaux fusiformes, pointes foliacées un peu épaisses et plusieurs petits poignards, l'un foliacé très allongé; un autre trièdre rappelle les séries déjà décrites (Tshikapa, Lupemba, etc.).

Série b.—Les autres objets dont la patine est un peu roussâtre, pourraient provenir, comme niveau primitif, de la limite des sables argileux gris et des sables argileux roux superposés, dont nous avons parlé dans la terrasse

supérieure. Cette série comprend de très remarquables objets: *poignards*, longs et effilés d'une magnifique facture, atteignant 20 à 30 cm., généralement foliacés fusiformes très allongés. Le talon est ou modérément pointu, ou obtus, et conserve un peu de cortex; parfois, il se renfle très faiblement. Le tiers de base (poignée) est généralement taillé seulement à grandes facettes, sans retouches secondaire; celles-ci, faites par pression, sont très soignées, s'étendant à tout le reste jusqu'à la pointe plus ou moins effilée. On retrouve les variations précitées de différences entre les deux faces et les deux bords latéraux: moins souvent la pièce est régulièrement biconvexe; plus généralement le verso, ce plan d'éclatement, est plus plat, et le recto, plus et parfois très bombé; son axe est souvent occupé par une arête médiane légèrement ondulée. Il est fréquent que l'un des bords tranchants soit plus soigné que l'autre; parfois l'un des deux est à retouches très abruptes de bas en haut, l'objet ne pouvant servir que par la pointe.

La plus grande pièce (Basanga, Lupemba) qui mesure 313 mm. de long est trop lourde pour avoir servi de poignard, et trop fragile pour un pic. Je l'imaginerais volontiers enchastrée par sa base, à angle droit, dans la tête d'une massue, à la manière d'une hallebarde. Les autres poignards de la série proviennent de Bandai sur Kasai, Basanga, Lupemba, Katoka (Lupemba), Kankulu (Bibanga).

Le même niveau de la surface des graviers de la haute basse terrasse a donné, de même origine dérivée, une série de pointes foliacées plus ou moins fusiformes, assez larges, parfois étroites; le recto est souvent un peu plus bombé que le verso, et il arrive qu'un bord latéral soit plus soigné que l'autre. On voit des types rappelant des ébauches solutréennes (de Laugerie-Haute), par exemple, et des formes ayant pu servir d'armatures de sagaies. Une de Bendai sur Kasai est une vraie feuille de laurier allongée, 10 cm., à base arrondie et extrémité effilée. On y retrouve les deux genres de facettes des feuilles de laurier européennes, les grandes facettes plates obtenues par percussion au bois sur le tranchant de l'éclat appuyé, et les fines retouches des bords, réalisées par pression. L'un de ceux-ci en est irrégulièrement dentelé, Le Still Bay d'Afrique du Sud a donné de pareils objets. Les plus lourdes des autres pièces peuvent trouver des comparaisons sporadiques dans le Fauresmith sud-africain et d'autres, quoique d'un autre travail, plus volumineuses, dans le Stellenbosch moyen et supérieur.

A côté de toutes ces belles pièces de haute technique, les ciseaux fusiformes à bout en taillant arrondi, faits sur éclat latéral, se retrouvent; l'un, de Kankulu (Bibanga), a servi aux deux extrémités, qui présentent des traces d'avivage.

Série c.—La patine blanchâtre de quelques pièces peut faire penser qu'elles seraient dérivées des sables rouges non stratifiés de la haute terrasse. Les deux pièces que j'en ai vues sont: une épaisse feuille de laurier fusiforme

large à bouts arrondis présentant des écaillures alternes témoignant de leur usage comme ciseau. L'asymétrie des tranchants indique que l'objet vient d'un éclat latéral.

L'autre objet foliacé, tronqué allongé, est plus exceptionnel; son bord large ogival en est l'extrémité utile à retouches alternes de ciseau ravivé, tandis que la partie effilée, laissée fruste, fait penser à son emmanchement.

C. *Sables fluviatiles de la basse terrasse supérieure niveau du Lupembien.*

On a dit que ce sable repose sur les graviers de la même terrasse. A ce niveau, apparaissent pour la première fois, en abondance, des lames régulières à deux ou trois pans, comparables à celles du Paléolithique, supérieur européen; leur fabrication suppose la taille au poussoir (baguettes de bois dur, d'os ou de pierre intercalées entre le percuteur et le nucleus callé). La matière première est plus choisie, on abandonne le grès polymorphe, lui préférant la calcédoine. C'est là un grand changement dans la technique de taille qui détermine une coupure archéologique; au Djokocien succède le *Lupembien*, qui, du reste, dérive du premier, ainsi qu'en témoignent des poignards, plus petits, des pointes de javelot, des dards et de vraies feuilles de laurier.

Outre des lames régulières portant des traces d'utilisation, on en trouve qui ont été transformées, par retouche, en instruments définis. Nous citerons un tronçon de lame (Lupemba I) à trois pans, dont le bord gauche tranchant a été retouché à maintes reprises, tandis que le droit laissé vif est finement mais irrégulièrement denticulé. Les extrémités sont rectangulaires. Un tel objet me rappelle les éléments d'outils complexes, tronçons de lame montés bout à bout dans une rainure de manche en bois ou os, qui, à mon sens, apparaissent déjà au Moustérien de Dordogne, se développent dans le Paléolithique supérieur d'Europe, et trouvent leur plus beau développement dans les faucilles d'Egypte et de Mésopotamie.

D'autres pièces, plus fréquentes, rappellent les pointes françaises de Chatelperron, à un dos abattu plus ou moins complètement, et l'autre laissé vif; l'un des quatre objets que j'ai vus a une tendance nette à réaliser un croissant fruste. On peut trouver des équivalents dans le Capsien Nord-africain ou dans le Middle Stone Age du Sud-Afrique. Mais les autres formes demeurent djokociennes; cependant on n'y retrouve plus de ces ciseaux, jusqu'ici si nombreux. Les poignards sont encore très nombreux; le plus grand 123 mm. est fusiforme à base tronquée de cortex, un peu courbe et fort bien retouché sur les deux faces, inégalement convexes (Lupemba, comme la plupart des pièces que j'ai examinées); un autre est foliacé épais, un peu losangique, à talon laissé un peu grossier; les retouches secondaires, générales sur les deux bords au verso, plus plat, sont limitées au bord gauche du recto; cette pièce, un peu raccourcie, dépasse 130 mm., sa pointe man-

quant. En revanche, de nombreux objets, de même manufacture générale que les poignards, mais de dimensions trop réduites, ont pu armer des sagaies; nous les appellerons pointes de dagues ou de javelot; leurs dimensions oscillent de 146 mm. à seulement 69 mm. et descendent à celles d'une "pointe de flèche." Il en est de très effilées, un peu épaisses, à base s'élargissant doucement, taillées vers celle-ci seulement à grandes facettes; des retouches secondaires se développent seulement dans les deux tiers de pointe. L'une, fusiforme, qui a plus de 88 mm., a les deux tranchants sinueux en sens inverse l'un de l'autre, lui donnant un mouvement de torsion. La plupart sont un peu trop épaisses pour une comparaison solutréenne ou Still Bay. Mais il en est d'autres qui méritent le nom de feuilles de laurier; l'une d'elles, parfaitement symétrique et fusiforme, présente au tiers de base d'un de ses bords une faible coche d'emmanchure. Une autre, lancéolée large à base arrondie un peu fruste, a 99 mm. La plus parfaite (175 mm.) est une splendide feuille de laurier, allongée, mince, très faiblement biconvexe, à base arrondie et pointe très aiguë; les deux tranchants sont parfaitement allignés par des retouches délicates superposées aux grands enlèvements transversaux plats. Ce magnifique objet rappelle les plus belles feuilles de laurier du Solutréen européen, du Still Bay, etc. Elle vient de Tshiniama (Lupemba).

A noter encore, n'ayant que 4 cm. de long (pointe de flèche?) une pointe foliacée à base élargieé.

Une autre, très usée par le sable, annonce une possible évolution vers l'industrie postérieure du *Tshitolien*, par sa base élargie à soie courte et ailerons naissants; sa partie de pointe est beaucoup plus développée que dans tous les objets néolithiques d'Europe.

De tels types se retrouvent, mais rares, dans le Solutréen français; ils sont nombreux, mais déjà plus définis dans celui de l'Espagne orientale; le Still Bay sud-africain n'est pas, que je sache, arrivé à cette différenciation.

On voit que le *Lupembien*, bien que continuant en partie la tradition Djokocienne, s'en "décroche," non seulement par la fabrication de nombreuses lames et outils dérivés, mais par la substitution aux armes manuelles, jusque là employées, des armes missiles, sagaies, et peut-être même flèches. Cette transformation de l'armement est évidemment d'une importance primordiale.

Industries du Plateau des Bena-Tshitolo au Nord de Bibanga.

Sur ce plateau cultivé, à un fer de bèche dans l'humus et dans les sables éoliens, qui en sont imprégnés, se rencontrent des silex taillés qu'il m'a paru raisonnable de diviser.

Série A.—Quelques uns, en effet, présentant de légères traces de ferriérète

comme il arrive aux pièces du Middle Stone Age sud-africain, dont c'est le niveau principal; on peut y rapporter six pièces de celles qui m'ont été soumises.

Ce sont deux petits éclats moustéroïdes à plan de frappe à facettes de préparation, dont l'un est assez lustré.

Un éclat subtriangulaire, assez mince, pointu, de grès polymorphe, et aussi d'aspect moustéroïde, à retouches très plates, des deux bords du recto; plus remarquable est le façonnement, par retouches bifaciales, de la base en un fort pédoncule entre deux épaulements bien développés mais arrondis, pas de vrais ailerons. L'objet a une curieuse saveur atérienne (Moustérien évolué du Nord de l'Afrique, de l'Egypte au Sahara Occidental).

Une autre pointe de trait, de chert jaspé blanc veiné de jaune, est fusiforme asymétrique; la base s'arrondit; l'autre s'étire en pointe très aiguë. Le bord gauche est presque rectiligne, tandis que le droit, un peu convexe, s'arrondit légèrement; tous les bords sont, sur chaque face, soigneusement retouchés par pression, et assez régulièrement denticulés. Sa longueur est d'environ 10 cm.

Une pointe de flèche proprement dite, en jaspe jaune, a une silhouette losangique, assez asymétrique tant en long qu'en large. Les quatre côtés sont légèrement concaves; la moitié de base plus courte que celle de pointe, présente une sorte de pédoncule assez timide.

Série A^1.—Bien que sans traces de ferricrète, on ne peut pas placer loin des pièces précédentes plusieurs pièces nous renseignant sur la technique vers cette époque, et antérieure, je pense, à la série B.

Ce sont: une pointe moustéroïde triangulaire ogivale, faite du remploi d'un petit nucleus de 6 cm. de long. Son verso, très plat et taillé de facettes très planes, montre à sa base un plan de frappe préparé soigneusement à facettes, d'où, au recto, sont parties plusieurs petites lames. Il a été régularisé à nouveau après cet enlèvement, et des retouches assez grossières, moustéroïdes aussi, ont façonné les deux bords latéraux en tranchants dentelés.

Un autre petit nucleus moustéroïde, ovale oblong (75 mm. de long) assez allongé, a le verso assez grossièrement taillé à facettes convergentes depuis tous les bords; les extrémités y sont biseautées légèrement par la préparation à petites facettes d'un plan de frappe à chaque bout. De l'un d'eux sont partis au recto deux éclats lamellaires avortés en charnières à mi chemin, après une retouche assez régulière mais un peu grossière de toute la surface.

De pareils petits nucléus bifaces, souvent remployés en racloirs, grattoirs ou pointes, existent dans divers milieux Middle Stone Age, surtout évolués, d'Afrique du Sud, spécialement au Transvaal et à Victoria Falls.

Au même petit groupe se rapporte une assez petite (7 cm.) feuille de

laurier mince, irrégulièrement losangique, à retouches bifaces très plates. Sa patine blanche a des souillures humiques sur une face; elle a été faite d'une petite lame.

Série B.—Tout l'outillage dérive de lames ayant la régularité de celles du Paléolithique supérieur européen, et dont une partie présente des facettes de préparation du plan de frappe sur nucléus.

L'un, de 6 cm. de long, un peu épais, a le bord gauche abattu presque perpendiculairement; l'autre est laisse vif. Cela réalise une pointe de Chatelperron, analogue à celles que nous avons vues dans le ***Lupembien***, mais peut-être plus évoluée.

Une autre lame, pas trop mince, comme la précédente, et à plan de frappe préparé, est seulement retouchée au verso, assez maladroitement, le long des deux bords latéraux, convergeant en une pointe acérée.

Il existe, parait-il, d'autres éclats ou lames retouchés, spécialement des grattoirs.

D'autres pièces sont retaillées sur les deux faces, comme un petit pic-ciseau fusiforme de 8 cm. de long, un peu sinueux. Sa base, tronquée par le plan de frappe primitif, est plus rétrécie que que l'extrémité utile, en ogive large et tranchante; des deux bords remontent sur chaque face les facettes de taille. Ce petit objet rappelle la série des pics-ciseaux Djokociens, mais est de dimensions plus plutôt réduites.

Ce qui caractérise, plus que tout, le ***Tshitolien***, est l'abondance des pointes de flèches et leur assez grande variété, contrastant avec leur absence au Djokocien, et leur extrême rareté au Lupembien.

J'en ai étudié 18, pouvant se ranger en trois groupes :

1^er^ *Groupe : Foliacées courtes et larges.*—La plus grande, mutilée des deux bouts, dépassait 8 cm. Une autre, fusiforme un peu épaisse, a la base pointue un peu réparée obliquement; son travail est très soigné, par pression comme pour les autres. Les deux autres n'ont que 3 cm. 5 de longueur, l'une, lancéolée, est un peu épaisse; l'autre, très mince, foliacée, est une pointe très acérée et à bords plus ou moins dentelés.

2^ème^ *Groupe : Foliacées allongées.*—Six, de 8 à 4 cm. de long. L'une est un peu épaisse, les autres plus minces. Trois montrent à la base une faible ébauche de soie, en un cas, consécutive à une réparation après fracture. On en trouve en Sud-Afrique dans les milieux Still Bay du faciès Howieson's Poort. Pas plus que les suivantes, elle n'approchent de la maîtrise dans la fabrication des pointes de flèche qui se voient dans le Néo-énéolithique égyptien, saharien et européen.

3^ème^ *Groupe : Pointes à soie.*—Il ne s'agit ni de pointes à longue soie du genre des pointes de la Font-Robert européennes, ni de celles, de technique moustérienne, de l'Atérien Nord-Africain; on est loin encore de la technique solutréenne d'Espagne orientale, déjà presque aussi habile que celle des

formes néo-énéolithiques; mais enfin le type est conçu et réalisé diversement, non sans gaucherie, dans sept pièces qui m'étaient soumises.

Une très petite (2½ cm. environ) est sublosangique, à quatre côtés concaves; la concavité peu accentuée des deux côtés de base y dégage une petite soie. Deux petites coches symétriques vers le milieu de l'objet ont dû servir à le fixer à la hampe avec un lien.

Une autre, mutilée, également losangique, asymétrique en largeur, devait atteindre 8 cm. Son tiers de base, qui forme soie, occupe la plus petite moitié du losange. La moitié de pointe, à peine plus large, est retouchée de denticules tout le long de ses bords. On sait que cette retouche denticulée est très répandue dans le Néolithique saharien.

Deux autres sont en demi-fuseau. La base de l'une, qui mesure encore 6 cm., est modifiée par deux profondes coches symétrique dégageant une très courte soie entre deux épaulements modérément saillants. La soie de la seconde est bien plus développée et s'étend sur tout le quart de base de l'objet; les épaulements sont peu saillants. L'objet est un peu épais (longueur 8 cm.).

Une autre a la soie bien définie par de petites retouches concaves symétriques de sa base, entre elle et des épaulements arrondis à peine naissants. Sa dimension a dû atteindre 5 cm.

Deux autres sont plus évoluées—l'une triangulaire, très forte, devait, complète, mesurer dans les 8 à 9 cm.; elle parait façonnée dans une feuille de laurier brisée au milieu en travers. Le pédoncule, actuellement mutilé, est produit par deux coches symétriques ayant dégagé sur les deux côtés deux forts épaulements. Leur saillie a été légèrement accentuée par quelques retouches concaves des deux bords vers le centimètre au-dessus, peut-être pour aider avec un lien à la fixation sur la hampe.

La dernière, également triangulaire et très mince, a le pédoncule très bien dégagé par deux coches symétriques assez creusées pour que les épaulements latéraux prennent l'aspect de vrais ailerons naissants.

Conclusions.

Jetons maintenant un regard rétrospectif sur les diverses industries de pierre taillée que nous venons de passer rapidement en revue.

I.—Dans les très vieux graviers des hauts plateaux de TENGO MUTUMBA antérieurs à l'hydrographie actuelle, nous avons vu les mêmes menus galets taillés par lesquels l'industrie humaine la plus ancienne se manifeste, comme dans la vallée du Vaal, en Uganda, au Kenya, et dans la plage sicilienne du Portugal. Il est fort probable que ces objets remontent tout au moins à la limite du Pliocène, si même ils n'y rentrent pas.

II.—Dans les graviers de la Kamoa, nous avons pu distinguer trois

groupes industriels, *Kamoens*, étroitement semblables aux divers stades de la vallée du Vaal:

A.—Le premier stade, très roulé, auquel il convient d'ajouter la pièce de l'Ile artificielle de Kawa, est comparable jusqu'à identité, avec le Stellenbosch I de Vereeniging, et tous deux sont identiques à l'industrie clacto-abbevillienne superposée directement à la plage sicilienne d'Abderrhaman à Casablanca (Maroc). Le débitage en est exclusivement clactonien, et beaucoup de bifaces sont façonnés sur grands éclats taillés sur enclume.

B.—Le second stade, non roulé, avec ses limandes et ses "cleavers," souvent sur éclats latéraux (cfr Victoria West) se réfère jusqu'à l'identité au Stellenbosch III–IV des graviers de fond de vallée du Vaal, à l'Acheuléen de Tachenghit (Sahara) d'autre part, et aux civilisations semblables du Kenya. Cela peut se comparer, moins étroitement, à l'Acheuléen français I–III de la Somme. Des faciès semblables existent aux Indes et dans l'Indus.

C.—Le troisième stade, à peine roulé, est comparable à des stades plus avancés du Stellenbosch du Vaal, et aux industries acheuléennes Marocaines superposées à la plage Tyrrhénienne d'El Hank (Casablanca). Les formes en sont aussi plus ou moins comparables à celles de l'Acheuléen picard IV–V.

III.—Des stades acheuléens plus évolués proviennent des éboulis de Luabo et de Lupweji, de l'argile sableuse kaolinifère de Ruashi, que je n'ai pu suffisamment étudier.

Il s'agit de stades correspondant probablement au Stellenbosch V des plus récents graviers du Vaal, et à l'Acheuléen final d'Europe Occidentale.

IV.—La haute terrasse de 90 mètres (mesure du sommet) du Kasai a permis de voir la suite des industries du vieux Paléolithique de cette région. La coupe de cette terrasse ressemble beaucoup à celle de la Riet River inférieure, dont le gravier de base contient du Stellenbosch roulé, suivi de dépots argileux ou argilo-sableux calcaires à Fauresmith de divers stades, suivis d'un niveau de ferricrète puis de sable rouge à Middle Stone Age que recouvrent des sables dunaires clairs à Late Stone Age. C'est paralèllement à cette évolution que nous placerons les divers stades découverts par le Docteur Cabu dans les graviers, argiles et sables de la terrasse de 90 mètres.

1.—*Les graviers ont livré.*—(A) Une série roulée constituée de pièces bifaces ovales ou fusiformes terminées en ciseaux ou gouges, dont on peut citer des analogues, du reste bien moins nombreux, dans les industries du Fauresmith du Transvaal et de Victoria Falls; c'est une sorte de petit acheuléen à orientation spéciale, centrée, semble-t-il, sur le travail du bois, et qui mérite le nom particulier de *KALINIEN*, en souvenir des fouilles à la pointe Kalina (Léopoldville) du regretté Mr. Jean Colette, qui l'avait d'abord fait connaître. Le débitage de cette industrie, est comme pour le Fauresmith, de technique levalloisienne déjà avancée; on sait que l'on rencontre

un débitage levalloisien plus archaïque dans les stades moyens et supérieurs du Stellenbosch, ce qui n'a pas lieu dans l'Acheuléen européen.

(B) La série peu roulée des mêmes graviers est toujours *kalinienne*, et comprend des ciseaux-gouges foliacés, ovales et lancéolés.

2.—Les sables argileux superposés au gravier ont donné la suite des mêmes outils *kaliniens*: pics et pics-ciseaux fusiformes, et un petit hachereau sur éclat latéral tout à fait Fauresmith. Mais on y voit apparaitre des armes pointues; certaines rappellent les types lancéolés du Fauresmith et de la Micoque (Acheuléen VII) et d'autres sont des bifaces fusiformes larges acheuloïdes, dont on connait des types sporadiques dans le Stellenbosch et le Fauresmith du Vaal. D'autres, également Fauresmith, rappelleraient d'épaisses feuilles de laurier taillées par percussion.

3.—Les sables argileux rouges superposés témoignent d'importants changements dans l'industrie; la tradition kalinienne s'y affirme par de nombreux ciseaux-gouges fusiformes ou foliacés larges; certaines de ces pièces s'allongent en véritables baguettes biconvexes ou trièdres à bords parallèles mais on voit apparaitre des pics très pointus, qui sont des armes, et l'un est assez petit pour avoir pu armer un javelot. On trouve néanmoins encore un biface lancéolé tout à fait Fauresmith-Micoque. Il y a là une transition à la civilisation *Djokocienne* qui va venir.

V.—La basse terrasse supérieure, à une centaine de mètres en contrebas de la précédente est le gîte ordinaire du *DJOKOCIEN*. Elle comprend ces graviers de base couronnés de sable.

1.—Les pièces les plus usées provenant des graviers ne diffèrent pas des séries antérieures dont elles dérivent probablement.

2.—Celles qui ne sont que lustrées, soit dans les graviers, soit à leur surface à la base du sable, constituent les séries du *Djokocien*. Les armes y prédominant complètement sur les outils: armes généralement *manuelles*, poignards aigus et allongés, petits et souvent très grands, voire si grands qu'on peut les penser montés en hallebarde; leur travail biface poursuit la technique Kalinienne, en y ajoutant cependant la retouche par pression. Des pièces foliacées, larges ou étroites, à pointe aiguë, évoquent un Solutréen ou un Proto-Still Bay un peu épais.

Il ne s'agit plus de Paléolithique ancien; on est probablement vers la base du Middle Stone Age sud-africain.

3.—Dansles sables mêmes, qui viennent ensuite, une nouvelle révolution s'opère, tant dans la technique de débitage, jusque là purement moustéro-levalloisienne, que dans la destination des armes.

Avec les lames on a fait, entre autres, des pointes de Chatelperron. Les poignards bifaces cèdent le pas à des formes dérivées, trop petites pour l'usage manuel, mais assez légères pour avoir armé des épieux: ces pointes de dard s'abaissent parfois à la dimension des pointes de flèche.

Des feuilles de laurier solutroïdes, parfois grandes et larges, d'autres fois fusiformes et foliacées, et de la dimension de la pointe de flèche, sont aussi une caractéristique nouvelle analogue au Still Bay sud-africain.

Une d'elles montre à sa base une ébauche de pédoncule. Cette apparition, probablement non exclusive de la technique des lames, et cette substitution des armes *missiles* (javelot) aux armes *manuelles*, nécessitent une nouvelle coupure dans la classification, le *LUPEMBIEN*, probablement comparable au Middle Stone Age sud-africain, et quoique bien différent, à une partie du Paléolithique supérieur européen.

Note infrapaginale I; le Middle Stone Age sud-africain est toujours un compromis ou complexe entre une tradition moustéro-levalloisienne et des éléments paléolithiques supérieurs.

VI.—*Plateau de Bena Tshitolo.*—La terre noire de Bena Tshitolo repose sur un sable rouge mêlé d'humus avec ferricrète à sa base. La culture en ramène, d'un fer de bêche de profondeur, des cherts de petite taille, probablement pas tous contemporains, car il en est à double patine.

1.—Un petit groupe, probablement plus ancien, avec traces de ferricrète assez fréquentes, comporte des petits nucléus moustéroïdes refaits en pointes ou racloirs moustériens; cela se produit fréquemment dans les mêmes formats, à des stades très évolués du Middle Stone Age du Transvaal et des Victoria Falls, à affinité de Still Bay.

Je crois devoir y ajouter une pointe de trait fusiforme épaisse, de tradition lupembienne, et une pointe de flèche losangique à soie naissante.

2.—Un groupe, sans trace de ferricrète, mais souillé d'humus, montre une généralisation de la technique des lames, avec grattoirs, racloirs et pointes de Chatelperron, et la floraison de nombreuses pointes de flèches courtes ou allongées, souvent à pédoncule dégagé plus ou moins, parfois à soie bien développée et ailerons naissants.

On semble être au début d'un développement de cette industrie des flèches; les types sont variables, comme formes et dimensions, et comme hésitantes dans leur réalisation de détail.

On peut, jusqu'à nouvel ordre, penser que l'on est à un stade final du Middle Stone Age, comparable au faciès de Howieson's Poort de la Province du Cap, et à l'évolution spéciale (plus évoluée ici) du Solutréen Supérieur du Parpallo (Alicante, Espagne Orientale).

Ce stade est ici caractérisé par le grand développement des *flèches* se substituant aux pointes de *javelot*; cela signifie que l'arc a pris la place de la projection manuelle et la flèche, celle de la sagaie. Une telle révolution industrielle réclame un nouveau nom: le *TSHITOLIEN*.

Il serait du reste bien nécessaire, pour le connaître de façon plus exacte, de réaliser des fouilles en cest endroit.

Plus d'un de nos lecteurs se demandera ce que devient dans cette affaire le ***TUMBIEN.***

Comme nous trouvons, en Europe, les coups-de-poing ou bifaces, autrefois tous *chelléens* par définition, répartis depuis l'Abbebillien (1er interglaciaire) à travers l'Acheuléen (2ème interglaciaire, 3ème glaciaire et 3ème interglaciaire), jusqu'au Levalloisien V ou au Moustérien de tradition acheuléenne (dernier glaciaire) de même les formes dites tumbiennes se voient aujourd' hui éparpillées sur les deux tiers de la durée de la Préhistoire congolaise.

Comme le terme de *chelléen* a dû, pour les préhistoriens avertis, être abandonné, car prêtant à mille confusions d'âges et de formes, de même le terme tumbien, établi sur une table de musée, à partir de récoltes sélectionnées de niveaux incertains, doit disparaître pour faire place à un vocabulaire mieux adapté aux réalités typologiques et stratigraphiques.

Ces deux appellations (chelléen et tumbien) correspondent à un stade de connaissances imparfaites, voire élémentaires, de la Préhistoire, qui doit céder le pas à une analyse objective et patiente des terrains et des industries. Celle-ci, inaugurée d'abord par M. Jean Colette, a été poursuivie à grands efforts et plus largement par le Docteur Cabu durant son séjour prolongé au Congo.

Dans un travail ultérieur, nous nous proposons d'étudier les industries également paléolithiques découvertes par le Docteur Cabu dans la plaine de piémont de Léopoldville.

Nous avons aussi le projet de donner le résultat de notre analyse des gravures de diverses techniques découvertes par le Docteur Cabu sur les parois d'une grotte-abri de Kiantapo aux sources de la Mulonga, dans les hauts plateaux du Haut Katanga, dont il m'a soumis de nombreuses et excellentes photographies.

Abbé Henri Breuil,

Membre de l'Institut de France ; Professeur au Collège de France et à l'Institut de Paléontologie Humaine, Paris; Professeur Honoraire à l'Université du Witwatersrand, Johannesburg; Attaché à l'Archeological Survey, Department of the Interior, Johannesburg.

25-1-1943.

Post Scriptum.

Les notes ci-dessus sont loin d'avoir épuisé l'étude des industries lithiques congolaises. Le Docteur Cabu ne nous a soumis que des échantillons d'industries qu'il considérait à juste titre commes les équivalents stratigraphiques et typologiques de l'Older et Middle Stone Age de l'Afrique du

Sud. Cette succession s'arrêtait au ferricrète et aux sables rouges parfois humiques qui s'y superposent.

Dans d'autres régions, sur les couches précédentes, ou dans des gravats récents où ils sont remaniés, se recueillent en abondance de petits instruments sur éclats de quartz, chert ou calcédoine à plan de frappe préparé ou non à facettes, principalement grattoirs, parfois microlithiques.

Des harpons à double rang de barbelures et des sagaies en os ont aussi été découverts récemment dans le parc National Albert par M. Damas qui seraient peut-être à comparer avec ceux du Sahara Méridional.

Il y a aussi le problème des pierres perforées ou "Kwes" que des observateurs sérieux pensent dans certains cas engagés dans le ferricrète ou enfouis dans des alluvions relativement anciennes.

Il y a aussi, sans contexte bien connu, des haches et herminettes d'aspect néolithique principalement en jaspe hématifère.

A mentionner encore les pierres à cupules, des polissoirs très nombreux fixes ou portatifs dans certaines régions, des morceaux d'ocre façonnés en formes de pains.

Il existe certainement d'autres manifestations rupestres de l'activité humaine que celles de la grotte de Kiantapo, une grotte à peintures schématiques rouges a récemment été signalée par M. van den Brande dans le massif des Marungu, rive Occidentale du Lac Tanganyika.

H. B.

LES INDUSTRIES PALÉOLITHIQUES DE LA TERRASSE DE 15 METRES ET D'UN CHENAL SECONDAIRE COMBLE, PLAINE DE PIEMONT DE LEOPOLDVILLE, D'APRÈS LES FOUILLES ET PHOTOGRAPHIES DU DOCTEUR CABU.

Par l'Abbé Henri Breuil.

(Read March 17, 1943.)

A des milliers de Kilomètres d'Elisabethville en creusant une vaste fouille qui demeure comme canal d'assainissement d'une région marécageuse, le Docteur Cabu a pu établir d'importantes successions de dépôts et d'industries préhistoriques, observations dont il fit sa thèse de Doctorat ès Sciences Anthropologiques et dont il a bien voulu me soumettre les données, en me priant d'exprimer par un rapport mes interprétations, si même elles devaient infirmer les conclusions de sa thèse. Mes vues confirment les siennes à tout point de vue, ainsi que l'on pourra s'enrendre compte ci-dessous par la description de pièces d'après les superbes photographies qui illustraient sa thèse.

I. Données Stratigraphiques.

Le canal creusé d'Ouest en Est dans la terrasse de 15 m., qui se retrouve également riche en industries à Kalina et de l'autre côté du fleuve à Brazzaville (A.E.F.), avait pour but de déjeter les eaux stagnantes de deux bras de la Belgica, dont le bras Est est arrivé à maturité complète et de les amener au fleuve Congo par un de ses affluents de gauche, la rivière Funa, d'aspect réjuvéné, fortement encaissée et à cours très tourmenté.

1. *Structure de la Terrasse.*—La section, du côté Est, présentait la complexité suivante:

La terrasse de 15 m. y était entamée par le chenal presque comblé, véritable marécage à Protoptères, du bras Est de la Belgica. Du côté Ouest, la berge du dit chenal montrait, sur la roche en place, un niveau de boulders et de gravier de base, surmonté par une couche peu épaisse de sables argileux gris; plus haut, venait un épais niveau d'argile rouge panachée; vers le bord de la rive, à son sommet, on voyait un lambeau superficiel de menus graviers. Le total de la section était de 7 m. aux environs du déversoir du canal dans la Funa.

Sur la rive opposée, la roche n'a pas été atteinte, mais on a retrouvé les

boulders et le gravier, surmontés de sables gris kaolineux assez importants, puis de l'argile rouge panachée, avec stade de tourbe vers le milieu de sa masse dans la berge de la rive droite du chenal dont nous allons dire quelques mots.

2. *Remplissage du chenal du bras Est de la Belgica.*—La fouille n'a pas traversé les sables jaunes d'or, apparemment stériles, stériles en tout cas dans ses deux derniers mètres vers le sommet de cette couche, sables jaunes d'or formant la base de la fouille dans ce tronçon.

Ils sont recouverts par des grès tourbeux, très cohérents à l'état humide, mais se désagrégeant à l'air. Leur surface, qui a été un sol, porte de nombreuses souches d'arbres *in situ*, à l'état de fossilisation par carbonisation interne, voire un atelier de taille à nombreux éclats à plans de frappe préparés ou non à facettes. Ces éclats ont une patine brune d'imprégnation d'humus décomposé.

Des sables blancs ont les recouverts, surmontés de dépôts marécageux récents, à couvert d'herbes de marais.

II. Contenu Archeologique des Couches de la Terrasse de 15 Metres en Dehors du Chenal.

A. *Graviers de base subanguleux, mêlés de boulders et de sables gris très fins, âpres au touché.*—6 Pièces grossières, d'aspect abbevillien, volumineuses, taillées à grandes facettes très remontantes, à talon de cortex conservé et larges surfaces naturelles; très altérées. Une des pièces semble un grossier pic de grande taille, d'autres sont piriformes plus ou moins allongés. Aspect très archaïque: *Stellenbosch I ou Abbevillien.*

B. *Sables argileux gris mélangés, recouvrant les graviers sur la rive Est du chenal.*—L'industrie découverte, faite de pics volumineux à patine d'un blanc crême, du type de *Stellenbosch* de Sud Afrique. Photos de trois pièces:—très gros coups-de-poing ovoïde, épais, à taille très remontante, sur éclats très épais clactonien, à plan de frappe oblique. Recto bien plus bombé que verso, à grandes facettes remontantes de *technique acheuléenne*; retouches secondaires assez soignées.—Gros éclat latéral épais, transformé en court "cleaver" (hachereau), massif, par des retailles peu importantes au verso, mais très remontantes sur les deux bords du recto. Probablement comparables au *Stellenbosch* II *du Vaal.*

C. *Sables gris blancs kaolineux recouvrant les graviers de base sur la rive Ouest du Chenal.*—D'après six pièces photographiées: *Stellenbosch III–IV du Vaal.* Deux pièces complètement bifaces, ovales paraboliques, de travail *acheuléen évolué*; la plus petite a la base légèrement renflée; l'autre, plus allongée et irrégulière, a l'extrémité formant un ciseau très ébrêché par l'usage.

Quatre autres pièces sont des ciseaux triangulaires allongés, à l'arc se rétrécissant jusqu'à être pointu dans l'un. Le bout large forme le taillant. Type fréquent dans le *Stellenbosch IV du Vaal*. L'un d'eux à été façonné à partir d'un éclat latéral (technique de *Victoria West*), comme les "cleavers" (hachereaux) du Vaal. Un autre, fusiforme tronqué, a ses bords latéraux retaillés légèrement concaves dans sa seconde moitié, aboutissant au ciseau à l'extrémité; le taillant de celui-ci n'a qu'environ la moitié de la largeur du milieu de l'éclat.

D. *Surface des sables argileux kaolineux.*—Fort éclat oblong, de technique clactonienne, à bords grossièrement parallèles, à large plan de frappe lisse et oblique, à gros bulbe de base. Les bords présentent une retouche dentelée et l'extrémité est un peu régularisée.

Tous les autres objets sont des bifaces; l'un est un fort hachereau massif, plus ou moins ovoïde, à taillant réparé en arceau peu régulier; travail *Stellenbosch-Acheul*.

Les autres bifaces sont allongés:—large pièce foliacée (0 m. 10) ayant des analogies dans le *Stellenbosch évolué* du Vaal. Des quatre autres qui s'allongent d'avantage, l'une ressemble à une ébauche de feuille de laurier épaisse. Une autre, à bords paralèlles, a le tranchant en chevron. Une dernière, fortement asymétrique, est en forme de D allongé, dont la barre présente des retouches presque verticales.

Le caractère de cet ensemble est analogue à l'industrie *Kalinienne*, décrite de Kalina par Jean Colette, et du Kasai, et a des rapports avec le *Fauresmith* du Vaal.

E. *Base de l'argile panachée rouge à nodules.*—Niveau très riche en objets. Les photographies m'en ont fait connaître les types suivants; deux grands éclats oblongs à large plan de frappe oblique de base. Les deux bords latéraux sensiblement parallèles sont entièrement et soigneusement retouchés en racloirs ainsi que l'extrémité arrondie en arceau parabolique et que le bord externe des plans de frappe.

Ces objets ont des analogues dans le *Levalloisien* et le *Moustérien* d'Europe, comme dans le *Fauresmith* de l'Afrique du Sud.

Les autres objets photographiés sont tous bifaces, les uns à silhouette fusiforme, plus ou moins foliacées épaisses, à pointes émoussées. Les autres, à bords presque paralèlles et assez accidentés, rentrent dans la série des pics-ciseaux à taillant convexe ou en chevron. Certains, plus larges et courts, ont la face inférieure plus plane. En somme, industrie où le pic fusiforme ou ovale parabolique domine complètement, très analogue au *Kalinien évolué* du Kasai.

III. Industries du Chenal.

A. *Grès tourbeux.*—Il y a lieu de considérer les objets recueillis comme appartenant à deux séries successives, dont la plus ancienne a des traces de roulis et d'altération accentuée. Elle est aussi plus grossière.

Série A.—Un éclat trapézoïde asymétrique montre un grand plan de frappe assez oblique avec quelques facettes et un gros bulbe; la pointe en est retouchée au verso sur les deux bords. Toutes les autres pièces photographiées sont bifaces, généralement épaisses et d'un travail grossier; ce sont en général de petits pics fusiformes, parfois à base un peu renflée. Une autre est en ovale tronqué à un bout.

Il s'agit encore de l'industrie Kalinienne, peut-être dérivée de la Série E.

Série B.—Beau biface lancéolé foliacé mince, admirablement façonné à tailles plates sur les deux faces, comparable à une pièce d'Elisabethville (Ruashi) de caractère *Fauresmith-Acheuléen* très évolué;—grand éclat levallois assez grossier à plan de frappe préparé à facettes;—fragment de poignard? oupic? réduit à sa base, très grossier;—pic-ciseau fusiforme. Nous somme toujours dans le *Kalinien* (Fauresmith à évolution particulière).

B. *Sable blanc recouvrant les grès tourbeux.*—Les pics-ciseaux fusiformes ou elliptiques, courts ou longs, y sont très abondants. L'un d'eux, court, atteint les proportions d'un pic campignien d'Europe avec un taillant large et droit. Le même taillant transversal droit se retrouve sur un autre à coupe ovalaire et sur des pièces soit bien plus allongées, en demi fuseau, soit courtes et assez petites; on en retrouve aussi à taillant en arceau.

D'autres encore méritent le nom de pics proprement dits, à terminaison mousse d'un côté et pointue de l'autre.

Il en est aussi de foliacés larges à base s'arrondissant et bouts arrondis également ou pointus. Certains fragments évoquent la feuille de laurier un peu épaisse. Certains rappellent le *Sangoen*, par leur verso retaillé en travers, vers la pointe, seulement vers le tiers de la longueur, vers le bulbe enlevé. Un ciseau long particulier a été réalisé sur une forte lame à bords paralèlles, gardant au vérso un plan d'éclatement lisse; les deux bords sont retouchés à facettes remontantes et façonnent entre elles, sur chaque face, dans l'axe du recto, une arête médiane dorsale. Le taillant est à l'extrémité, mais forme un tranchant légèrement convexe, fort bien retouché de larges facettes plutôt paralèlles, obtenues par pression.

A côté de ces outils, se retrouvent des armes à pointe aiguë, moins épaisses que les premières et trop fragiles pour en avoir servi; ce sont des types foliacés, un peu épais pour des feuilles de laurier européennes; une partie sont un peu lourdes pour avoir armé des javelots, mais ont pu, emmanchées, servir de poignards; d'autres plus petites, ont pu avoir cette dernière destination.

L'ensemble parait indiquéz un *Kalinien* évoluant fortement vers le *Djokocien*, mais n'ayant pas les beaux types de poignard du Kasai.

C. *Niveaux superposés dans le Chenal aux sables blancs et terrasse de 15 mètres en dehors du Chenal à la surface des argiles sous le sol végétal sableux.*—Il s'agit d'une petite industrie à lames et menus éclats bien venus; on y note la continuation des pics-ciseaux de dimension plus réduite, mais surtout la présence de nombreuses pointes de flèche. La plupart sont foliacées assez courtes, d'autres s'allongent beaucoup. Un petit nombre ont des bords dentelés, et quelques-unes des petites saillies latérales analogues à des barbelures incipientes.

A côté de ces feuilles classiques se reconnaissent un assez grand nombre de micro-tranchets triangulaires ou trapézoïdes façonnés sur fragments d'éclat mince. Leurs bords latéraux sont abattus verticalement, comme dans les séries microlithiques et néolithiques d'Europe. S'agit-il de Néolithique? Tout indice de poterie manque!—ou de facies tardif du Middle Stone Age final, le Tshitolien déjà remanié à Bena Tshitolo?

De nouvelles fouilles sont nécessaires pour lever tous les doutes sur ce point précis de ce stade très évolué, d'autant plus que dans le sol végétal le Docteur Cabu a recueilli, en, je ne les ai pas vus, des microlithes en quartz reconnus pour tels par le Professeur Carl Absolon et d'autres lors du Congrès International de 1935 à Bruxelles.

Abbé Henri Breuil,

Membre de l'Institut de France; Professeur au Collège de France et à l'Institut de Paléontologie Humaine, Paris; Professeur Honoraire à l'Université du Witwatersrand, Johannesburg; Attaché à l'Archeological Survey, Department of the Interior, Johannesburg.

30-1-43.

Je suis tout particulièrement reconnaissant à Monsieur l'Abbé Breuil d'avoir voulu consacrer quelques semaines de son temps précieux à l'examen approfondi du matériel lithique et des photographies de gravures rupestres que j'avais emportés pour les lui soumettre, ainsi que le problème du Tumbien.

Ma thèse de doctorat (elle condamnait le prétendu Tumbien, civilisation prétendûment apparentée au Mésolithique de prétendus éleveurs de porcs) et mon exposé au Congrès International de Bruxelles en 1935 n'étaient connus que de quelques-uns et avaient, sauf au Congrès, de rares détracteurs. Leurs objections, faites en dehors de la discussion publique de ma thèse de doctorat dont ils connaissaient le lieu et la date, et au Congrès auquel ils n'assistèrent pas, se faisait insidieusement, basée principalement sur le fait que je faisais des assimilations avec le matériel du Vaal et du Cap que je n'avais pas ou insuffisamment manipulé.

Ensuite des circonstances de guerre, j'eus l'occasion non seulement de

manipuler à loisir les outillages des divers horizons archéologiques des collections de l'African Museum et de l'Université de Capetown, du Archaeological Survey (Université de Witwatersrand), de Bulawayo (Rhodésie du Sud), du Livingstone Institute (Rhodésie du Nord), mais j'emportais, outre un film cinématographique sur mes fouilles, de nombreuses photographies prises au cours de celles-ci et un échantillonnage important (plus de 300 pièces) que je considérais comme Earliest, Earlier et Middle Stone Age, principalement, car c'était le point à affirmer avec force. Non seulement j'ai étudié et manipulé, dans les vitrines et tiroirs des collections, et sur les lieux mêmes de quelques gisements, le matériel archéologique sud-africain et des Rhodésies, mais le Professeur C. van Riet-Lowe et MM. A. J. H. Goodwin, B. D. Malan et Neville Jones et d'autres ont manipulé pendant ce même laps de temps, puis interprété avec une parfaite unité de vues, les pièces congolaises. Une note du Professeur van Riet-Lowe dont un extrait parut dans le S.A.M.A.B. (South African Museums' Association Bulletin, juin 1941), soulignait la diversité des stades paléolithiques congolais menant du très vieux pré-Stellenbosch au Middle Stone Age. Le savant directeur de l'Archaeological Survey, tout comme le Professeur Goodwin, confirmait les analogies que j'avais affirmées en faisant précéder du préfixe "Belgian Congo" les industries de types Stellenbosch et Fauresmith. Cette manière de désigner nos industries anciennes avait pour but de déterminer à la fois et des analogies de techniques, de typologies, et de conditions de gisement, et les non similitudes principalement dues à la différence du matériau employé dans des aires géographiques si éloignées les unes des autres et si dissemblables au point de vue de la géologie du sous-sol. Monsieur l'Abbé Breuil vient de confirmer et ma thèse et les jugements de mes amis et collègues sud-africains, et ce, de tout le poids de son autorité mondiale au point de vue spécialement de la typologie, classification, comparaison et assimilation.

Monsieur l'Abbé Breuil reconnait lui aussi toute une série évolutive partant d'un "very dawn" commun avec l'Afrique du Sud du Paléolithique le plus ancien à travers *l'Abbevillien* et les stades *Acheuléens* du *Stellenbosch* et du *Fauresmith*, à partir duquel nos industries prennent des facies qui ne sont pas spécialement congolais puisqu'on parlait de Tumbien, non seulement au Congo Belge, mais à l'Est et au Nord du Congo. Monsieur l'Abbé Breuil, à partir du Fauresmith, reprend, sur ma proposition, les dénominations de feu Jean Colette: *Kalinien*, puis *Djokocien*, tout en signalant leur position par rapport au Fauresmith et industries qui en dériveraient, pour les compléter par les stades évoluant du Djokocien: le *Lupembien* d'abord et ensuite: le *Tshitolien* (termes nouveaux). Ce Tshitolien parait devoir terminer le Middle Stone Age, congolais tout au moins, mais rester à préciser, j'en conviens, par des fouilles plus nombreuses et plus étendues.

En quelques semaines, Monsieur l'Abbé Breuil eut non seulement la grande amabilité de consacrer à la préhistoire congolaise tout son temps et son grand savoir, mais il rédigea les trois des quatre notes que je viens de présenter en son nom et avec son approbation.

Le Gouvernement Général du Congo Belge, faisant écho aux desiderata exprimés par le Professeur van Riet-Lowe, MM. Goodwin, Malan, Neville Jones et d'autres, de tenir le plus rapidement possible, un congrès d'archéologues africains afin de mettre au point des questions générales ayant trait à l'Afrique, vient de marquer son accord de principe au sujet de la réunion à Elisabethville de ces Assises scientifiques dès que la guerre aura pris fin.

Le Professeur Henri Breuil en assurerait la présidence d'honneur et c'est pourquoi il a traité le problème de nos industries dans toute son ampleur, rejetant, comme impropre, comme il le fit pour le Chelléen, le terme de Tumbien inventé par Oswald Menghin, qui lui-même rectifia à plusieurs reprises sa position dans le classement des industries archéologiques. Le Tumbien est condamné à disparaître complètement, et à tout jamais, de la littérature et, après la condamnation prononcée par moi-même d'abord, puis confirmée par les Professeurs Goodwin et van Riet-Lowe, sa condamnation en termes non équivoques est maintenant une fois pour toutes, signée Henri Breuil.

Docteur FRANCIS CABU,
Chargé de Mission au Congo Belge.

NOTES ON DR. FRANCIS CABU'S COLLECTION OF STONE IMPLEMENTS FROM THE BELGIAN CONGO.

By C. van Riet Lowe, D.Sc.,

Director, Archaeological Survey, Department of the Interior, Union of South Africa; Professor of Archaeology, University of the Witwatersrand, Johannesburg.

(Read March 17, 1943.)

I have handled and examined every one of the 331 stone implements Dr. Francis Cabu brought to Johannesburg from the Belgian Congo. The collection includes type specimens forming a series of cultures that includes —from the bottom upwards:

1. Pre-Stellenbosch or Pre-African Abbevillian Pebble Culture artifacts that recall the Kafuan forms of Uganda (S.A. 159, 160, 161, 162, 163, 165).

2. A single but very typical Oldowan Pebble tool (S.A. 260) that could have come from Olduvai itself.

3. A single African Abbevillian (Vaal Stellenbosh I) biface (S.A. 164).

4. Early, Middle, and Late Cape Stellenbosch forms: hand-axes, cleavers, and discoidal artifacts on both cores and wide-angled Clacton-like flakes.

5. Typical Vaal Stellenbosch III hand-axes and cleavers on large side-flakes that reflect a mastery of the Proto-Levallois I or Victoria West I technique.

The affinities between the implements from Kamoa and those from the Vaal River Younger Gravels II at Riverview Estates near Windsorton,* the Kagera River M-Horizon at Nsongezi on the Uganda-Tanganyika border, the Kariandusi River in Kenya, the Kenya Acheul IV of Olduvai in Tanganyika, as well as the palaeolithic tools (hand-axes and cleavers) from the Presidency of Madras in India are most marked. In all these areas we find (*a*) hand-axes on cores (usually water-worn pebbles) as well as on wide-angled, Clacton-like flakes, and (*b*) cleavers almost exclusively on side-flakes where the business or working (cleaver) edge is made up of two intersecting flake surfaces—*i.e.* a tool with positive bulbs or flake surfaces on both the upper and lower faces—and generally parallelogrammic in cross-section (*cf.* S.A. 123). The "*bloc-en-bloc*" anvil technique that

* van Riet Lowe, C.: "The Archaeology of the Vaal River Basin," Geol. Memoir No. 35, Govt. Printer, Pretoria, 1937.

characterises the Clacton and Tachengit and the "*wood-on-stone*" technique that characterises the Acheulean Culture are integral parts of a common whole. In other words, both these techniques were practised by folk who enjoyed the same material culture; there is no vertical division between the essentially flake and core techniques in the Congo as there apparently is in Western Europe. The situation is precisely the same throughout Africa from the basin of the Nile to the Cape of Good Hope.

The culture represented in the KAMOA assemblage is a perfect counterpart of the so-called "Hand-axe Culture" of comparatively advanced Acheul facies as it is known in India, Somaliland, Kenya, Uganda, Tanganyika, the Rhodesias, South West Africa, and the Union of South Africa.

6. A Congo variation of the Sangoan Culture of Uganda with strong Fauresmith affinities or, it is equally true to say, "a Congo variation of the Fauresmith Culture with strong Sangoan affinities," *i.e.* a culture that includes advanced Acheul-type bifaced tools and Sangoan picks in intimate association with an advanced Levallois technique.

The assemblage from MIKALAYI is particularly interesting: while many of the bifaced (handaxe-like) tools are of Fauresmith type, the majority in the collection examined vary from thickish *limande* forms (that do occur in the Fauresmith but are not too common) to more slender ? Proto- or ? Early Stillbay forms—*i.e.* they are rather Sangoan than Fauresmith in general contour. I use the expressions ? Proto- and ? Early Stillbay not in the sense in which Dr. Leakey uses them in Kenya, but merely to suggest possible ancestral Stillbay forms, *i.e.* to define the type of biface I would expect to occur between the typical advanced Fauresmith "hand-axe" and the typical Stillbay bifaced "point."

(The Mikalayi assemblage also includes many tools that have in the past been referred to the "Tumbian"—which in reality is a *mélange* of Mid- and Upper Palaeolithic, Mesolithic, and Neolithic forms—viz. Advanced Acheul, La Micoque and Combe Capelle bifaced tools (*i.e.* Fauresmith), ? Proto-Stillbay, Sangoan picks, Stillbay points, Aterian and Sbäikian bifaced points (including pedunculate forms), ground and polished axes, and pottery. I therefore fail to see how the term can be retained in the sense in which it was originally used, and I have in consequence avoided it.)

The double-pointed (*limande*) bifaced tool of Mikalayi and elsewhere is common in the Congo, but comparatively rare in the Union. On the other hand, the Fauresmith Culture includes cleavers (on both end- and side-flakes) but no picks, while its Congo "counterpart" includes picks but few cleavers—yet both the Congo and the South African variations of the culture include the same forms of hand-axe in intimate association with advanced Levallois cores and flakes—tools and *debitage* which are in all respects identical.

While I therefore recognise in the MIKALAYI assemblage a variation of the Sangoan Culture of Uganda, I also recognise unmistakable affinities with the Fauresmith of the Union.

I must, however, add that I have for long considered the Nanyukian Culture of Kenya, the Sangoan of Uganda, the Fauresmith of South Africa, and possibly the Shäikian of North Africa to be local variations of a more widespread common cultural whole. The tools manufactured vary slightly from region to region, but the basic techniques in all these cultures are identical. This applies particularly to the Levallois. So much is this the case in the Nanyukian *vis-à-vis* the Fauresmith, that Leakey resolved in 1938 to rename the Nanyukian the "Kenya Fauresmith."

Travelling westward from Kenya to the Congo Basin—or northward from the Union to the Congo—we find what appears to be the same culture as the Fauresmith with picks and a few cleavers instead of cleavers only. We have the same small handaxe-like bifaced tools tending toward bifaced points, and precisely the same Levallois cores and flakes. In other words, I venture to suggest that when the Sangoan of Uganda is better known it (like the Nanyukian) will be found to be related to the Fauresmith, and I therefore suggest that the culture represented by the Mikalayi industry be tentatively named the Congo Fauresmith—although I have no real objection at this stage to the retention of the term "Kalinian" provided that the affinities between this culture and the more general Fauresmith are stressed.

7. *The Djokocian Culture.**—This is a culture that is not known in the Union—yet it contains numerous Stillbay bifaced forms in intimate association with a more advanced Levallois technique than that that typifies the Congo Fauresmith. There are unmistakable affinities between the Djokocian and the Stillbay of South Africa on the one hand and the Djokocian and Aterian of North Africa on the other. Where the Stillbay is characterised by slender (laurel and willow leaf) bifaced points made from flakes struck from a core prepared in a very advanced Levallois manner, the Djokocian is characterised by long slender pick-like tools (asymmetrically biconvex to pseudo-rectangular in cross-section over the minor axis) and bifaced points that include Stillbay forms that are usually more massive and asymmetrical in cross-section—the whole, however, in intimate association with a very advanced or sophisticated Levallois technique. This basic technique provides, I feel, an important link not only with the Stillbay of the South but also with those cultures that include the advanced Levallois in other parts of Africa.

Many of the tools that I have in the past considered to be "Tumbian" occur in this Djokocian Culture. Some years ago, Dr. Jacques described

* Bequaert, M.: "Les Fouilles de Jean Colette à Kalina," Ann. du Mus. Congo Belge, Mars 1938.

a large series of implements excavated in the Congo by M. Hass at Tumba. Although I am convinced, as I have indicated above, that the collection from Tumba included types from different cultural horizons, yet the types illustrated by Leakey in figs. 9 and 19 of his "Stone Age Africa" have rather generally come to be regarded as the most characteristic tools of the so-called "Tumbian Culture," *i.e.* rather thickish bifaced implements, the majority of which were used as "points," but some of which were undoubtedly used for other purposes—such as "picks" and "gouges" or even daggers.

The question of terminology in the Congo is one that I am not competent to discuss in detail at this stage. It is essentially Dr. Cabu's problem.

8. *The Later Stone Age.*—Dr. Cabu's large collection also includes numerous Later Stone Age (Mesolithic to Neolithic) elements:

(i) S.A. 170 is a typical Early Smithfield "trimming-stone" or "core-scraper" with most characteristic step-flaking.

(ii) S.A. 322 is a typical Middle Smithfield "trimming-stone" or "core-scraper."

(iii) A group of a dozen or so unnumbered specimens in cloudy quartz from Elizabethville includes typical Middle Smithfield end- and side-scrapers.

It is with these tools that M. P. van den Brande, geologist to the C.S.K., discovered the engraved stone referred to as a "phallic statuette" or "engraved figurine." In my opinion, the stone is a natural ferruginised pebble of shale—which does not discount the possibility that it was used as a phallic emblem and decorated as Dr. Cabu believes. The type of engraving is unknown to me.

(iv) Numerous bored stones suggest the occurrence of Congo variations of the Smithfield and Wilton Cultures, while

(v) Ground and polished axes, one ground stone with fine geometrical engravings, pottery, etc. bring us to the Neolithic Age.

9. *Summary of Conclusions.*—There can be no doubt that Dr. Cabu's collection of stone implements represents the evolution of human craftsmanship through many cultural stages from Pre-Palaeolithic to Neolithic times. The occurrence of Kafuan and Oldowan types reflects the occupation of the basin of the Congo by man in Early Pleistocene, if not in Pliocene times. The Earliest Kafuan implements I saw in Uganda occur (rolled and unrolled) in an ironstone band at the base of the 270-foot terrace of the Kagera River near Nsongezi. According to Wayland this deposit is possibly Late Pliocene (on Haug's definition of the line of demarcation between the Pliocene and Pleistocene).

Then follow the Oldowan (S.A. 260) and African Abbevillian (S.A. 164) forms, which in time give way to the Congo Stellenbosch. This in turn is

superseded and replaced by the Congo Fauresmith or Kalinian (of Mikalayi), which is followed by the Djokocian and later a "Middle Stone Age Complex" that reveals a complete mastery over the most advanced Levallois technique. Finally we have elements of the Later Stone Age with its Mesolithic and Neolithic types, the latter being very common in several areas.

The study of Dr. Cabu's collection is made particularly easy because of his excellent documentation. Every specimen is accompanied by notes on its setting—notes on the geological frame from which it was extracted.

I do not intend to make any reference to the climatological background of the various lithicultural horizons, for, while Dr. Cabu's photographs and notes make it obvious that the basin of the Congo survived climatic variations of much the same nature as did other parts of Africa during the Pleistocene and that man's movements were affected by these fluctuations (alternating wet and dry periods), Dr. Cabu's study of these conditions does not, I feel, justify elaboration at this stage. Nevertheless, I wish to congratulate him most sincerely on the vast amount of research already achieved as well as on the outstanding results he has obtained. For the first time are we now able to see the Congo not as the home of a single Stone Age culture (the ill-conceived "Tumbian" of Oswald Menghin) but as a vast stage upon which man has practised his skill from the very dawn of the Pleistocene right up through the millennia to the present. That prehistoric man passed through many evolutionary stages in the basin of the Congo in much the same way as he did in other parts of the continent—North, Central, and South Africa—is no longer open to question.* Let us hope that Dr. Cabu will soon be able to publish the results of his labours—elaborating the climatological backgrounds of the various cultural horizons—and so cast more light on the evolution of human craftsmanship in an ever-changing environment in an area about which we have hitherto known all too little. It is a most important area in that it contains some of the oldest types of stone implements hitherto recognised—pebble tools of the Kafuan and Oldowan Cultures. I have for long felt that Central Africa is a probable source of man's earliest efforts to make and use implements of stone and that it was from this region that elements of some of the oldest known material cultures (such as the Pre-Abbevillian, Abbevillian, and Acheulean) were carried north to Western Europe, south to the Cape, and eastwards as far as India. My researches in the prehistory of Uganda during the years 1937 and 1939 confirmed earlier suspicions.† They also led me to recognise the importance of the basin of the Congo, for although my work did not take me west of the Kivu-Albertine Rift, I found a greater wealth of Kafuan

* *Cf.* Vayson de Pradenne: La Prehistoire, 1938.

† Wayland and van Riet Lowe: "The Pleistocene Geology and Prehistory of Uganda," in Press, Govt. Printer, Entebbe.

types along the western border of Uganda than anywhere else in the Protectorate or in East Africa, where I was privileged to do field work with Leakey during 1937.

Up to the present, Dr. Cabu has found very little Pre-Stellenbosch or Pre-African Abbevillian material but it is there, and the Congo is a vast territory. We must therefore be patient and, while we may hope for much during his lifetime, we must recognise the limitations of a lone worker in the little time that is available in so vast a territory.

(Written May 3, 1941.)

IMPROVED UNIVERSAL BUFFER SOLUTIONS.

By Edgar Newbery.

(With two Text-figures.)

(Read May 19, 1943.)

Introduction.

Among the numerous buffer solutions which have from time to time been described, the so-called "Universal Buffers" have proved specially useful. This is due in part to the fact that they have a much greater range than any of the simpler buffer mixtures, and partly because they afford a ready means of preparing a buffer of any required pH, within specified limits, by the application of a simple equation which may be written on the label of the container.

The best known of these universal buffers are the Prideaux-Ward and the Britton-Robinson mixtures, both of which are described in the textbook "Hydrogen Ions" by Britton.

Of these two, the former has the wider range, the pH between the limits 2·5 and 11·5 being given by the equation

$$\mathrm{pH} = 0{\cdot}733 + 0{\cdot}1185x,$$

with an accuracy of $\pm 0{\cdot}2$ pH, which is sufficient for most colorimetric pH measurements.

(The term "accuracy" is here used to denote the maximum difference between the observed pH and that calculated by means of the equation given.)

For more accurate work, the Britton-Robinson mixture gives pH values between the limits 3·7 and 8·3 by the application of the equation

$$\mathrm{pH} = 2{\cdot}686 - 0{\cdot}0853x,$$

with an accuracy of $\pm$ 0·05 pH. Above pH 9 it is less accurate than the P.-W. mixture, and pH values must then be taken from the published tables and not calculated from the equation.

In both equations, x represents the number of c.c. of 0·2 *N*. NaOH added to 100 c.c. of the stock buffer and the whole made up to 200 c.c.

The Ideal Buffer.

An ideal universal buffer should have the following qualities: (*a*) long range, (*b*) an accuracy of 0·05 pH throughout its useful range, (*c*) easily made from reasonably cheap and readily available pure materials, and (*d*) good keeping qualities. The P.-W. buffer fulfils conditions (*a*) and (*c*) but not (*b*). The B.-R. buffer fulfils condition (*b*) over a range of 4·6 pH only, and barbitone is a rather expensive ingredient.

With regard to condition (*d*), since phosphate and citrate solutions promote bacterial and mould growths, some fairly powerful preservative is needed for both of the above buffers, specially for the B.-R.

Finally, the 0·2 *N*. alkali for use with these buffers is troublesome to prepare, owing to the precautions necessary to avoid the presence of CO_2, and must be preserved in paraffin-lined containers fitted with soda-lime guard-tubes.

Experimental.

A long series of experiments has been carried out, mainly on the basis of modifications of the P.-W. and B.-R. buffers, though a few new mixtures were also tested. Some of the acids used were carbonic, lactic, salicylic, methyl salicylate, chloracetic, and phenol.

It was soon found that the condition for straightness of the curve stated by Britton (Hydrogen Ions, p. 227), that consecutive pK's must not differ by more than 1·23, is valid only when a single polybasic acid is concerned. If two or more acids are used, and any two pK's fall too close to each other, the solution will be over-buffered in that region and the curve distorted.

Since the B.-R. mixture shows very good accuracy over a limited range, attention was first concentrated on lengthening this range without disturbing the section between pH 3·7 and 8·3.

Above pH 9 the B.-R. mixture is markedly *under*-buffered due to the long interval between the pK of boric acid (9·2) and of HPO_4 (11·6). The addition of an acid with a pK of 10·4 should therefore straighten this part of the curve.

The only suitable acid which could be found with a pK in this region was phenol. Phenol is cheap and readily available in a very pure form, but is somewhat difficult to weigh accurately in exact quantities owing to its hygroscopic nature, and its keeping qualities are not ideal. Its pK of 10·0 is not very close to the ideal of 10·4, but in spite of this, experiment showed that it has a remarkable effect in straightening the upper part of the B.-R. curve, and further that no discoloration occurred when the acid stock buffer was kept for nine months in a half-filled glass bottle with temperatures varying between 50° and 100° F.

In order to extend the range in the acid region, sufficient HCl was added to replace the K in the KH_2PO_4. Since this mixture now contains 9 replaceable H ions in place of the 7 of the original B.-R. mixture, the total concentration was made 0·25 *N*. instead of 0·2 *N*., and 0·25 *N*. NaOH was used for preparing individual buffers. One litre of this mixture contains:

KH_2PO_4	3·78 gm.	Barbitone	5·12 gm.
HCl *N*.	27·8 c.c.	H_3BO_3	1·72 gm.
Citric acid (H_2O)	5·84 gm.	C_6H_5OH	2·61 gm.
Preservative soln.*	1 c.c.		

100 c.c. mixture treated with *x* c.c. N/4 NaOH and diluted to 200 c.c. Interpolation formula, pH = 1·40 + 0·1*x*.

x.	Observed pH.	Calculated pH.	Error.
0	1·90	1·40	+ 0·50
10	2·41	2·40	+ 0·01
20	3·36	3·40	− 0·04
30	4·41	4·40	+ 0·01
40	5·48	5·40	+ 0·08
50	6·48	6·40	+ 0·08
60	7·47	7·40	+ 0·07
70	8·45	8·40	+ 0·05
80	9·48	9·40	+ 0·08
90	10·32	10·40	− 0·08
100	11·28	11·40	− 0·12

The range of this buffer is equal to that of the P.-W. mixture, and the accuracy of ± 0·08 pH between the limits 2·5 and 10·5 is a little less than that of the best portion of the B.-R. range. The remarkable simplicity of the interpolation formula is a useful feature.

The chief disadvantage of all the buffers discussed lies in the need for NaOH soln. free from CO_2, a solution which is troublesome to prepare and also to preserve.

In order to avoid this, it was decided to *invert* the buffer by using fully saturated sodium salts for preparing the stock buffer and N/4 HCl for adjusting the pH.

Such a solution made up with anhydrous salts should contain in 1 litre:

Na_3PO_4	4·55 gm.	$NaBO_2$	1·83 gm.
Na_3 citrate	7·17 gm.	$NaOC_6H_5$	3·22 gm.
Na barbitone	5·72 gm.		

* An alcoholic solution containing 2 per cent. chlor-o-phenyl phenol and 2 per cent. thymol.

Sodium phenate is difficult to prepare in the anhydrous form: di-sodium phosphate is usually more readily available in a pure form than the tri-sodium salt, and the common forms of sodium citrate and meta-borate contain 5·5 and 4 mols. of water of crystallisation respectively. Hence a more convenient formula for making up the same solution in the laboratory is:

NaOH N/1 soln.	55·6 c.c.	Na barbitone	5·73 gm.
$Na_2HPO_4 12H_2O$	9·94 gm.	$NaBO_2 . 4H_2O$	3·82 gm.
Na_3 citrate $5{\cdot}5H_2O$	9·90 gm.	C_6H_5OH	2·61 gm.
Preservative soln.	1 c.c.		

The interpolation formula for this buffer between 10·5 and 2·5 is

$$pH = 11{\cdot}57 - 0{\cdot}103x,$$

where x is the number of c.c. of N/4 HCl added to 100 c.c. of the stock buffer and made up to 200 c.c.

x.	Observed pH.	Calculated pH.	Error.
0	11·36	11·57	−0·21
10	10·52	10·54	−0·02
20	9·51	9·51	0·00
30	8·53	8·48	+0·05
40	7·48	7·45	+0·03
50	6·43	6·42	+0·01
60	5·39	5·39	0·00
70	4·32	4·36	−0·04
80	3·31	3·33	−0·02
90	2·31	2·30	+0·01
100	1·95	1·27	+0·68

The accuracy of this buffer between pH 2·5 and 10·5 is $\pm 0{\cdot}05$, and is therefore equal to that of the B.-R. buffer in its optimum range between 3·7 and 8·3. Its keeping qualities, however, are not perfect. After one month in a clear glass bottle exposed to full daylight, including direct sunlight, a distinct brownish tint developed. Nine months later the brown tint was unchanged, but a slight sediment had formed although the pH was unchanged. Such discoloration is undesirable for indicator work and, if required for this work, the stock solution would probably keep better in an amber glass bottle, preferably in a dark cupboard. Since, however, colorimetric work rarely requires an accuracy better than 0·1 pH, and the next buffer to be described not only fulfils this condition but also does not discolour on exposure to light, the above buffer is needed only for potentiometric work, in which case colour is immaterial.

The greater accuracy of this inverted buffer as compared with the original acid mixture appears to be due to some slight buffering action of the excess sodium chloride smoothing out the curve. It was thought, therefore, that some similar improvement might be realised by inverting the much simpler P.-W. buffer.

The original P.-W. buffer utilises phosphoric, boric, and phenylacetic acids, but in the alkaline version of the same there is no special advantage to be gained by using the sodium salt of the last acid, and the cheaper and more accessible sodium acetate was therefore substituted.

This solution contains in 1 litre:

Na_3PO_4 6·56 gm. CH_3COONa 3·28 gm. $NaBO_2$ 2·64 gm.;

or, using hydrated salts,

$Na_2HPO_4 12H_2O$	14·32 gm.	$CH_3COONa 3H_2O$	5·44 gm.
NaOH N/1	40 c.c.	$NaBO_2 4H_2O$	5·52 gm.

Interpolation formula from pH 11·0 to 2·3 is

$$pH = 12{\cdot}11 - 0{\cdot}108x,$$

where x is the number of c.c. of 0·2 *N*. HCl added to 100 c.c. of the stock buffer and made up to 200 c.c.

x.	Observed pH.	Calculated pH.	Error.
0	11·60	12·11	−0·51
10	11·10	11·03	+0·07
20	9·97	9·95	+0·02
30	8·92	8·87	+0·05
40	7·75	7·79	−0·04
50	6·64	6·71	−0·07
60	5·63	5·63	0·00
70	4·54	4·55	−0·01
80	3·50	3·47	+0·03
90	2·36	2·39	−0·03
100	1·91	1·31	+0·60

The accuracy of this buffer, ±0·07 pH, is considerably better than was expected, and its range covers most purposes for which such buffers are used. Its keeping qualities are good, and it is the least expensive of the five buffers discussed in this paper. No preservative was added and, except for the deposition of a slight sediment, it has kept clear and colourless for nine months.

The pH curve obtained with this buffer is shown in fig. 1, and the

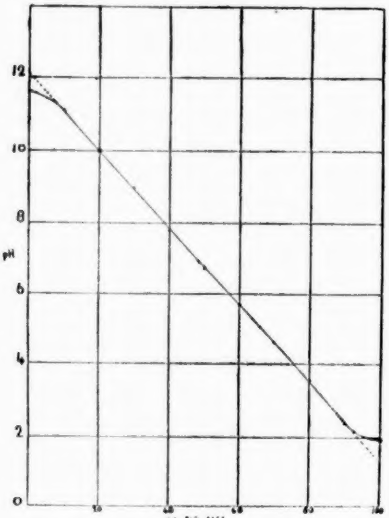

FIG. 1.—Percentage neutralisation with HCl. Newbery's Universal Buffer Mixture.

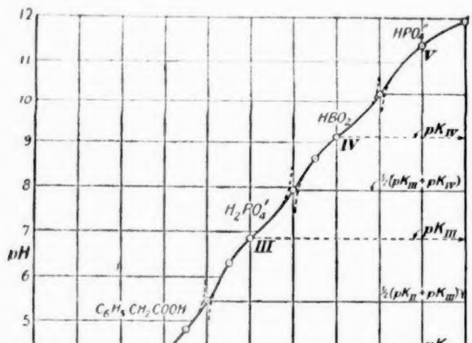

FIG. 2.—Percentage neutralisation with NaOH. Prideaux and Ward's Universal Buffer Mixture.

corresponding P.-W. curve, which has been taken from Britton's textbook, p. 226, in fig. 2.

For convenience in making up a buffer of any required pH, the following table shows the corrected number of c.c. of N/5 HCl to be added to 100 c.c. of the stock buffer before making up to 200 c.c.:—

pH.	c.c.	pH.	c.c.	pH.	c.c.
2·2	91·8	5·2	64·0	8·2	36·1
2·4	89·6	5·4	62·2	8·4	34·5
2·6	87·9	5·6	60·3	8·6	32·8
2·8	86·2	5·8	58·3	8·8	31·1
3·0	84·4	6·0	56·3	9·0	29·3
3·2	82·7	6·2	54·3	9·2	27·3
3·4	80·9	6·4	52·3	9·4	25·4
3·6	79·0	6·6	50·3	9·6	23·5
3·8	77·1	6·8	48·5	9·8	21·6
4·0	75·2	7·0	46·7	10·0	19·8
4·2	73·2	7·2	44·9	10·2	18·0
4·4	71·3	7·4	43·1	10·4	16·2
4·6	69·4	7·6	41·3	10·6	14·5
4·8	67·6	7·8	39·5	10·8	12·7
5·0	65·8	8·0	37·8	11·0	11·0

Keeping Qualities of these Buffers.

Discoloration or clouding may be produced by (*a*) chemical changes, (*b*) bacteria, or (*c*) moulds. The original P.-W. stock buffer appears to keep indefinitely, solutions being perfectly clear and colourless after keeping for two years. Made-up buffers between pH 5 and 6 are badly discoloured in three months, whilst those above 9 may deposit a slight sediment but keep colourless.

The original B.-R. stock buffer appears to grow bacteria and moulds vigorously. Thymol inhibits bacterial growths but not moulds, and fluffy balls of mould over 1 cm. diameter appeared in two months in a stock bottle containing 0·05 gm. thymol per litre. A small piece of silver foil kept in the bottle seems to check this growth, but its action is rather doubtful.

The modified acid B.-R. buffer, made up as described, has kept clear and colourless since it was made up nine months ago.

The poor keeping qualities of the inverted B.-R. buffer have already been mentioned.

It appears, therefore, that the thymol + chlor-o-phenyl phenol preservative is effective in acid but not in alkaline solution, and a suitable preservative for the full range of pH is unknown to the author.

Practical Details.

The pH measurements were carried out with the aid of a Tinsley "Vernier" potentiometer, using two independent hydrogen electrodes with each solution. Platinised glass and *Pt* plate electrodes were used, one electrode receiving electrolytic H_2 from a U-tube generator with *Ni* electrodes, and the other from a cylinder of the compressed gas. Below pH 7, values were further checked with a quinhydrone electrode.

Most of the chemicals used were of A.R. quality, and their characteristics are described in Britton's textbook.

Tri-sodium phosphate, as purchased, contains 12 mols. of water of crystallisation, but is unreliable in this form due to the presence of carbonate. Heating for half an hour at 750° to 800° C. expels this CO_2 along with all the water, and pure dry salt is obtained.

Anhydrous sodium phenate may be obtained by dissolving pure phenol in petrol and adding sodium wire. The excess of sodium is removed, the salt filtered rapidly in a sintered glass filter and dried *in vacuo* with silica gel to absorb petrol vapour. The anhydrous salt, preserved in sealed glass tubes, is not discoloured by exposure to direct sunlight.

Sodium citrate may be dehydrated by heating to 150°–200° C. for 30 minutes. Sodium metaborate may be dehydrated by heating small quantities in a large dish until intumescence is completed, breaking up the mass and reheating to dull redness.

Summary.

Three new buffers are described, the first having long range, simple interpolation formula, and good keeping qualities, but requiring the use of CO_2-free NaOH. The second has slightly better accuracy and utilises HCl instead of NaOH, but its keeping qualities are not good. The third is the simplest and cheapest to make, utilises HCl, and has good range, accuracy, and keeping qualities.

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THE RELATIONSHIP BETWEEN THE MICROSCOPIC STRUCTURE, FIELD CHARACTERS, AND PHYSICAL PROPERTIES OF CAPE ROAD STONES.

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(With Plate III.)

(Read March 17, 1943.)

CONTENTS.

1. Introduction.

In recent years highway engineers have become increasingly conscious of the need for care in the selection of suitable aggregates in their road construction schemes. The problem has been until latterly less urgent in South Africa than in densely populated countries, for, except in the vicinities of large towns, the Union roads seldom bear heavy traffic. Now that the construction of a complete network of National Roads had been initiated, and is likely, in times of peace, to carry an ever-increasing number of road vehicles, the choice of suitable road aggregates has become of paramount importance. The disastrous consequences of using poor aggregates are already visible in many parts of the country. In the Witwatersrand much useful work on road materials has been carried out by Professor B. H. Knight and his associates, but there is no evidence that highway engineers as a body are alive to a situation which has been aggravated by war conditions. In many countries it is customary before using a particular aggregate in any important construction scheme to determine the physical properties by standard methods in order to estimate its probable behaviour as a good road stone. The figures thus obtained serve as a most useful basis for comparison since a large amount of data is already available.

Some of the most informative tests, however, are lengthy and can only be carried out with the aid of expensive apparatus difficult to obtain, especially in war time. Need for rapid inexpensive methods is clear.

The examination of thin sections of aggregates by means of the polarising microscope seems to present the best solution of the problem. The advantages of this method were early realised, and the well-known monographs of Lovegrove, Flett and Howe (1) with their systematic investigation of British road stones remain classics. In recent years Professor B. H. Knight (2) has been one of the strongest advocates of microscopic petrology as an aid to the highway engineer.

The authors have been able to carry out physical tests, using standard methods on all the road stones used for main roads on a large scale in the Divisions of the Cape, Paarl, and Stellenbosch. All the aggregates have been examined microscopically, and in every case the quarry from which they were obtained was visited. Microscopic examination of road stones is a most important adjunct to, or even a substitute for, the standard physical tests, but it is only reliable if backed by an adequate knowledge of the field characters. There appears to be insufficient emphasis of this point in current literature. The case of stratified rocks may, in particular, be referred to. Many quarries in which sedimentary aggregates are worked, show alternations between such widely different types as quartzite and shale. Both are included in the aggregate which comes from the crushers, but tests on either alone would be completely misleading. Quartzite is in general a good road stone, while shale is invariably poor. Samples collected by uninformed persons from such a quarry would in general consist of quartzite, which has a fresh appearance, though much shale might appear in the crushed aggregate. Numerous cases of such faulty sampling came before the authors and made clear to them the great importance of first-hand information as to field characters.

The present communication is an attempt to assess the values of standard physical tests, field examination, and microscopic examination used in conjunction and apart. The authors believe that systematic surveys of this kind, even of limited scope, serve to establish a common meeting ground for the petrologist and civil engineer, to the advantage of both.

2. Acknowledgments.

Through a grant from the Staff Research Fund of the University of Cape Town and the co-operation of the Cape Provincial Council we were able to obtain a Deval Attrition Machine, a Page Impact Machine, a Dorry Abrasion Machine, and a diamond drill for preparing test cylinders. In collecting material we received every assistance from the Divisional Councils of the

Cape, Stellenbosch, and Paarl. In this connection we are particularly indebted to Mr. I. Cohen and Mr. W. Schutz of the Cape Divisional Council and to Mr. Vos, Town Engineer, Paarl. The enthusiastic co-operation of these gentlemen, and of Mr. Clifford Harris of Messrs. R. H. Morris Ltd., greatly expedited the field work. Every facility to carry out the investigation was given by Professor A. E. Snape, Professor of Civil Engineering, University of Cape Town, to whom we are sincerely indebted.

3. Field Data.

In the district under consideration three formations are available as aggregates in main-road construction—that is, in roads which are called upon to carry medium or heavy traffic.

1. Malmesbury Series (Malmesbury blue).
2. Cape Granite.
3. Table Mountain Sandstone Series (T.M.S.).

The Malmesbury Series of unknown age has been injected by the Cape Granite, both formations being unconformably overlain by the early Devonian Table Mountain Sandstone Series. Full descriptions of the local development of all three formations have been given by Haughton (3).

1. *Malmesbury Series.*

The Malmesbury beds present very similar characteristics in all the quarries in which they are worked. The chief type is a "fine compact argillaceous quartzite" of dark blue-grey colour, but in every quarry it is interbedded with a slaty modification considerably poorer in silica. The slaty bands are relatively small in bulk and usually under two feet in thickness. The strata have been subject to intense folding and invariably dip at a high angle (60–90 degrees). They possess a very conspicuous cleavage generally coincident with the bedding planes and are often traversed by crush bands. Many of the bedding planes show slickensiding and are coated with chlorite. A well-marked series of joint planes is developed perpendicular to the cleavage, and other oblique sets are also to be detected. Some of the quarries show numerous quartz veins running in all directions.

The Malmesbury beds of the district lie in the contact aureole of the Cape Granite and have therefore been subjected to metamorphism in varying degree. This has produced a toughening effect with a distinct improvement in their qualities as road aggregates. The more altered varieties have the appearance of a hornfels. Close to the granite, which is not exposed in any of the working quarries, the cleavage planes become less

conspicuous and the argillaceous bands lose their slaty appearance to become a compact spotted hornfels. Under the hammer the rock is exceedingly tough, except in the slaty bands which break readily into laminae. Broken fragments may show conchoidal fracture but are more often irregular or flaky. This is confirmed by examination of the crushed aggregate, which shows a large proportion of flaky fragments. Some of these fragments consist of slaty material, but many of them represent the normal siliceous modification. Their presence is distinctly detrimental to the aggregate as a road stone, and is, indeed, its sole disadvantage as such. The toughest and least flaky portions of the rock may be detected by their tendency towards conchoidal fracture and by the pinkish sheen of minute flakes of fresh biotite. The occurrence of quartz veins has no adverse effect, but the introduction of much material from the crush zones is deleterious, since it is friable and easily weathered.

Although the Malmesbury formation is covered in many places by very thick deposits of drift or material which has weathered in place, it shows very little decomposition when used as a road or concrete aggregate.

Except for its tendency towards flaky fracture and its shaly bands it can be reckoned, judging by its characteristics in the field, as an exceedingly good road stone.

2. *Cape Granite.*

Three distinct facies of the Cape Granite occur in the area under consideration, but each is uniform in texture and composition besides being relatively free from inclusions.

(*a*) Porphyritic biotite-granite of the Peninsula and Flats.
(*b*) Biotite-granite of the Paarl mass.
(*c*) Muscovite-biotite-granite of Brackenfel and the Schapenberg.

(*a*) The porphyritic biotite-granite of the Cape is worked in only one quarry, that of Klip on the Cape Flats, where large exfoliating domes project through the sandy soil. Like all other occurrences of this formation it contains abundant phenocrysts of white potash felspar, which largely determine its characters as a road stone. Their large size and perfect cleavage is opposed to the relatively fine grain and toughness of the matrix, causing local differentiation in the wearing qualities of the stone as a whole, particularly when it is used as chippings. Moreover, the cleavage cracks of the large felspars render the rock somewhat permeable to water and hasten decomposition. Proof of this is found by examining dumps in abandoned quarries, a few years' exposure having rendered the stone yellow and friable. Its field characters, in short, indicate that it is a poor road stone in spite of its freshness, cubical fracture and uniformity.

(*b*) The biotite granite of Paarl is quarried at several points along the

eastern side of the Paarlberg, where the rock is exposed in enormous domes. In all these workings two prominent sets of joint planes may be seen, one parallel to the exfoliation surfaces of the hillside, and the other vertical with a general north-south trend. The rock is even-grained, very uniform, and has a good cubical fracture, but incipient decomposition of the felspar, shown by a certain dullness, has somewhat reduced its toughness. It is, like the Klip granite, poor in aplite veins and xenolithic inclusions, and is determined in the field as a road stone of medium qualities unsuitable for heavy traffic.

(*c*) The muscovite-biotite-granite of the Schapenberg and Brackenfel masses is worked on a large scale at Brackenfel. Except for the addition of muscovite to the essential minerals, it strongly resembles the Paarl granite. The jointing is similar and also the evenness of grain and dull appearance through incipient decomposition. Portions of the rock show a distinct pink coloration, probably through the development of montmorillonite or some manganiferous product. Xenolithic inclusions are unimportant, but aplite veins are prominent. They do not, however, detract from the qualities of the stone as a road aggregate, for they are tougher than the normal rock. Crush zones are much commoner than in the Paarl quarries and have an adverse effect on the aggregate. Judged by the field characteristics, the Brackenfel granite is slightly inferior to that of Paarl as a road aggregate and is therefore unsuitable for heavy traffic except in pre-mix bituminous carpets.

3. *Table Mountain Sandstone Series* (*T.M.S.*).

The T.M.S. is worked on a large scale in Glencairn quarry, where the Main Sandstone is exposed in horizontal layers. These consist for the most part of tough resistant quartzite of grey or green colour, cubical fracture, and fine to medium grain; but they are interbedded with micaceous and shaly bands which are so soft as to render them useless as a road aggregate. Material from these layers, if included in the crusher aggregate, is highly detrimental. The field characters of the quartzite indicate that, if it can be obtained free from shaly and slaty matter, it is likely to prove an excellent road stone.

Other Aggregates.

The aggregates described above are used more or less satisfactorily in bituminous roads designed to bear medium or heavy traffic, but others of poorer quality are also employed: the most important being:—

(*a*) Durbanville Gravel (= ferricrete or lateritic iron-stone).
(*b*) Surface limestone from Wetton District (= calcrete).
(*c*) Slightly weathered Malmesbury Blue.

All three aggregates are of superficial occurrence and exceedingly variable in quality. They are nowhere quarried on a large scale, nor are they crushed mechanically.

(*a*) The widely used Durbanville gravel is the best quality lateritic iron-stone in the Cape district. It is a very hard concretionary rock full of voids and of typical yellow-brown colour. The workings extend over a wide area west of Durbanville race-course, but are nowhere deep. For a deposit of this material the rock is of good quality. Similar deposits of inferior gravel are worked on a smaller scale at several localities.

(*b*) The surface limestones or calcretes of the Cape Flats consist of angular to subangular quartz-grains embedded in a very abundant cream-coloured matrix of soft, fine-grained calcite. They are of widespread occurrence though quite superficial. Both depth and hardness are very variable. The Wetton district supplies many workings for road aggregates.

(*c*) The overburden of the Malmesbury Blue is of variable character, but directly above the unaltered blue stone there is a slightly weathered zone of neutral tint and incipient shaly lamination which is worked as a water-bound road aggregate in the western Tigerberg. In spite of a certain tendency to split into laminae it is a fairly tough rock.

Owing to their sporadic occurrence in the field and very variable properties none of the three aggregates is suitable for roads designed to bear other than light traffic.

4. Microscopic Data.

I. *Microscopic Data: Granites.*

Mineral Composition by Weight (Mode).

	Klip.	Paarl.	Brackenfel (coarse).	Brackenfel (fine).	Malmesbury (micro-granite).
Quartz . . .	32	38	44	46	4
Potash Felspar .	28	24	22	26	24
Plagioclase (An_{25-35})	29	31	23	20	24
Muscovite . .	1·5	0·5	3	2	..
Biotite . . .	9	6	8	6	6
Accessories . .	0·5	0·5	0·5	0·5	0·5

The accessories in every case include apatite, zircon, and iron ore. Titanite is found in the Malmesbury and Paarl rocks.

(a) *Texture.*

Klip.—The rock is markedly porphyritic large crystals of white potash felspar (up to 3 cm. long), being embedded in a coarse ground mass of

granitoid texture and grain size about 1·3 mm. The crystals interlock well, but the cleavage of the large phenocrystals is likely to prove a serious source of weakness.

Paarl and Brackenfel (coarse) (Plate III, fig. 1).—Both rocks show normal granitoid texture with the crystals interlocking well. The grain size is smaller than that of Klip quarry rock, being 1·2 mm. in the Paarl rock and 1·1 mm. in Brackenfel. The absence of phenocrysts and finer texture are likely to result in a stronger aggregate than that of Klip.

Brackenfel (fine) and Malmesbury Microgranite (Plate III, fig. 2).—Both rocks show good, even-grained micrograniti texture (grain size about 0·25 mm.) with excellent interlocking of the crystals. The microscopic aspect indicates that they are likely to prove of high quality as road stones. Although the Malmesbury microgranite lies outside the area under consideration, it is included as being the best rock on which tests were made. A chemical analysis of it is quoted below.

Flaser Granite, Malmesbury, 1 Mile along Paarl Road.—This rock is also outside the area, but is included since it is a typical product of cataclastic metamorphism. The unaltered rock must have had a texture similar to that of the Paarl granite, but shearing has caused mortar structure to develop and has chloritised the biotite. The finely ground quartz and felspar are a source of strength, but the streaks of chlorite on the other hand form a distinct structural weakness most undesirable in any road aggregate.

(b) *Decomposition.*

A certain amount of decomposition has taken place in all the above rocks tending to reduce their strength for road aggregates. It is more marked in the coarse Brackenfel and the Paarl rocks than in the others. The Brackenfel stone is on the whole the worse of the two. The first mineral to suffer is the plagioclase which becomes saussuritised. The finer granitic rocks are by no means exempt from decomposition, but the effect is not so serious as in the coarse granites for the strains set up therein by changes of volume are slighter.

Grading of Granites as Road Aggregates based on their Microscopic Characters.

Very good:	Micrograniites of Brackenfel and Malmesbury.
Very fair:	Brackenfel (coarse) and Paarl.
Poor:	Klip quarry and Malmesbury (Flaser rock).

II. *Microscopic Data: Malmesbury Series.*

Mineral Composition of Argillaceous Quartzites.

Quartz.—Well-graded subangular grains up to 0·4 mm. about 50 per cent.
Oligoclase.—Do., but much less abundant.

Biotite.—Minute flakes and aggregates up to 0·2 mm. up to 10 per cent.
Chlorite.—Do.

(Various minute grains too small for accurate determination.)

Accessories.—Tourmaline, garnet, iron ore, zircon.

Texture (Plate III, fig. 2).

The clastic grains are firmly cemented without voids of any kind and since they are of small size and subangular shape the rock is likely to be tough. The biotite flakes tend to form fringes round the clastic minerals, increasing their relief. They have in addition a slight tendency towards parallelism, though not enough to be classed as schistose. This is a possible source of weakness.

Decomposition.

Both quartz and plagioclase felspar are generally unaltered, but in some rocks the biotite is chloritised. This may also be detected in the hand specimen by the slightly greenish appearance and absence of pink sheen. The chlorite pseudomorphs the mica exactly, being never migratory; thus the possibility has to be considered that such rocks contain primary chlorite and belong to a lower grade of metamorphism than the biotite-hornfelses. The Faure specimens are nearly all chlorite-bearing and contain considerably less tourmaline than the biotite-bearing rock of the De Waal Drive quarry, which is probably much closer to the granite contact. It is possible, however, that the tourmaline may be clastic and unconnected with the intrusion of the granite.

The fine grain, freshness, and compact nature of the rock indicate a road stone of excellent quality. The slaty type, however, contains more mica, with a greater tendency towards parallelism and considerably fewer clastic grains. Its qualities as a road stone are therefore likely to be much inferior.

III. *Microscopic Data, T.M.S.*

Mineral Composition of Quartzite.

Quartz in sub-angular grains averaging 0·7 mm. is the only essential mineral. The grains are closely packed in a sparse quartzose cement.

Accessories include felspar in clastic grains (microcline and sodic plagioclase), muscovite, garnet, and iron ore in smaller grains.

Texture.

In spite of medium grain size and absence of grading in the quartz grains, the rock is exceedingly compact, all the intergranular spaces being

entirely filled by quartzose cement. Bands somewhat coarser or finer than 0·7 mm. grain size are found, and sporadic pebbles of vein quartz or quartzite may occur sparsely, but the relationship of the constituents remains the same. The subangular character of the clastic grains allows a certain amount of interlocking, and the muscovite flakes are too small in quantity to cause cleavage. In the shaly bands, which are of frequent occurrence in Glencairn quarry, muscovite is exceedingly abundant, and this mineral together with argillaceous material renders the rock so fissile that sections could not be prepared. The shaly bands may pass into a fissile micaceous sandstone of intermediate character.

Decomposition.

When the Glencairn quartzite is exposed to the elements for some time, it tends to become somewhat saccharoidal and friable, but the newly quarried green or grey rock is quite unaltered.

The microscopic characters of the Glencairn quartzite indicate a tough road stone of excellent quality, but, if much shale is allowed to enter the crusher aggregate, its effect will be exceedingly deleterious.

IV. *Microscopic Data: Other Aggregates.*

The gravels and calcretes do not lend themselves to microscopic examination, but the sections of the surface quartzite of Parow show it to be a very

TABLE I.

CHEMICAL DATA.

	1.	2.	3.	4.	5.	6.	Analyst W. H. Herdsman.
S_1O_2 .	73·32	73·50	73·28	70·34	74·98	59·24	1. Granite, Schapenberg
Al_2O_3 .	12·49	13·78	13·57	14·81	10·63	18·32	(= Brackenfel).
Fe_2O_3 .	0·39	0·54	0·44	0·28	0·27	0·34	2. Granite, Paarl (Municipal
FeO .	2·30	1·51	1·95	2·92	4·64	6·72	quarry).
MnO .	..	0·04	..	0·02	0·04	0·09	3. Microgranite, 5 miles N. of
MgO .	0·72	0·52	0·62	1·21	1·33	3·47	Malmesbury.
CaO .	0·75	1·86	1·46	1·90	2·08	1·33	4. Porphyritic Granite (mean of
Na_2O .	2·28	3·02	2·89	2·20	2·19	2·84	two closely agreeing analyses
K_2O .	4·54	4·73	4·36	4·84	2·06	3·66	= Klip quarry).
H_2O+	0·79	0·22	1·02	0·65	0·41	2·59	5. Malmesbury quartzite (Sonne-
H_2O-	nil	0·16	0·13	0·16	0·09	0·20	blom quarry, De Waal Drive).
TiO_2 .	0·18	0·25	0·26	0·42	1·05	1·22	6. Malmesbury slate (Wyllies
P_2O_5 .	0·09	..	0·07	0·03	0·17	0·15	Siding).
Totals	99·85	100·13	100·05	99·78	99·94	100·07	

Analyses 1–4 quoted from C. B. Coetzee, Trans. Geol. Soc. S.A., 44, 1942, p. 199.
5 and 6 are new analyses.

variable rock, some portions being a compact chert, while others are porous disclosing clastic quartz grains in a silty cement. It is not likely to prove a satisfactory road aggregate.

The high ridge of grit running N.W. of Klipheuvel Station is extensively quarried for harbour works and railway ballast, though not much used as a road aggregate. Under the microscope it proves to be a typical grit. Angular to subangular grains of quartz and sparse felspar (0·8 mm. grain size) are embedded in an abundant matrix of silty quartz and minute mica flakes. The lack of interlock of the clastic grains and abundance of mica in the cement are likely to prove distinct sources of weakness if the stone is used as a road aggregate.

5. Physical Tests.

The test specimens for all physical tests were selected and prepared in accordance with the requirements of the British Standard methods for the sampling and testing of mineral aggregates (B.S. No. 812, 1938).

The test specimens required for the abrasion, impact, and crushing tests are cylinders one inch in diameter and one inch long, the ends being plane surfaces at right angles to the axis of the cylinder.

Abrasion Test.—Two one-inch diameter cylindrical specimens are dried and weighed and are held with their axes vertical and lower ends pressed with a weight of 1250 grms. against the surface of a horizontal cast-steel disc. The specimens are fixed in sliding sleeves opposite to each other, and each 10 inches from the centre disc. The disc is turned through 1000 revolutions at a speed of 28 to 30 revolutions per minute, while dried Leighton Buzzard sand is fed continuously upon the disc. Upon completion of the run, the specimens are weighed again and the coefficient of hardness determined by the formula:

$$\text{coefficient of hardness} = 20 - \frac{\text{loss of weight in grms.}}{3}.$$

Impact Test.—A cylindrical specimen is held securely on an anvil and axially under a plunger. A continuous series of blows are given by a hammer weighing 2 kg. arranged so as to fall freely between suitable guides. The fall of the hammer is 1 cm. for the first blow with an increase of 1 cm. for each succeeding blow until failure of the test specimen. The height of the final blow in cms. indicates the toughness of the stone. A good road stone should withstand at least 18 blows.

Crushing Strength.—All compression tests on the 1-inch diameter stone cylinders were made between smooth plane steel plates. One compression plate of the machine was provided with a ball seating to ensure axial and uniform load distribution.

A rock which crushes with a load of less than 10,000 lb. per sq. inch is unsuitable for use as a road stone (4).

Attrition Test.—5 kgm. (11 lb.) of clean dry stone passing a 2-inch sieve, but retained on a ½-inch sieve, are weighed accurately and transferred to a cylinder inclined at 30° from the horizontal. This cylinder is rotated through 10,000 revolutions at 30 r. per minute. The contents are then washed free from dirt and particles under 1/16 inch in diameter and weighed after drying to constant weight. The percentage loss of weight is then determined, and the test repeated with the addition of 5 litres of water. The mean of the wet and dry tests is taken as the loss by attrition. The French coefficient of wear is generally quoted as equal to

$$\frac{40}{\text{per cent. loss by attrition}}.$$

The best rocks for road-making give an attrition value of under 2 per cent. Rocks which give high attrition losses are not satisfactory for road-making. The sieving, weighing, washing, heating, and carrying out of this test is a laborious process compared with the preparation and testing of the small cylinders used for the abrasion, impact, and crushing strengths.

An attrition test takes up a full day, whereas each of the other tests can be carried out in one hour.

The figures cited in Tables I and II agree well with those for corresponding rock-types quoted in U.S. Department of Agriculture Bulletin, 370, pp. 13–100, but the American tables include no type exactly comparable to the slightly hornfelsed argillaceous quartzites of the Malmesbury Series.

6. Discussion and Interpretation.

Abrasion Test.

Against
1. Dissimilarity to road conditions.
2. Difficulty of obtaining standard sand.
3. Element of variability introduced by differences in rate of feed of sand.

For
1. Short time required for test (1 hour).

Impact Test.

Against
1. Marked effect of "shake" veins and similar irregularities on result.

For
1. Ease and great rapidity (½ hour).
2. Close correlation with field characters and microscopic structure.
3. Compact nature of apparatus.

TABLE II.

PHYSICAL PROPERTIES OF CAPE ROAD STONES.

Type and Locality of Stone.	Mean Crushing Strength, lb. sq. in.	B.S.S. (Page Impact Test) (No. of blows to cause failure).	B.S.S. (Deval) Attrition Test, Loss per cent.			French coefficient of Wear.	B.S.S. (Dorry) Abrasion Test of Hardness.	Absorption of Water.	Specific Gravity.
			Wet.	Dry.	Mean.				
GRANITES.									
Klip Quarry, Cape Flats	6,300	9	7·96	4·62	6·29	8·66	19·1	0·44	2·66
Brackenfel, coarse	16,500	11	5·54	4·70	5·12	8·51	..	0·29	2·66
„ aplitic	21,500	22	..	..	..	..	..	0·18	2·56
Paarl:									
Jacobs & Muller	20,500	12	..	..	..	..	..	..	..
Municipal Quarry	15,800	13	5·11	3·84	4·47	10·03	..	0·44	2·63
N. Paarl Quarry	22,600	11	..	..	..	..	..	..	..
Malmesbury:									
Flaser Rock	18,500	10	..	..	..	..	..	..	..
Micrograpite	35,200	31	..	..	..	..	..	0·19	2·60
MALMESBURY QUARTZITE.									
Fairfield Quarry	21,400	18	4·83	3·12	3·97	12·82	..	0·28	2·77
Faure Quarry	26,700	30	..	..	..	..	..	0·18	2·70
Tigerberg (R. H. Morris)	20,100	28	..	..	..	..	..	0·17	2·72
„ (C. D. C.)	17,700	34	..	..	..	..	..	..	..
De Waal Drive	23,000	29	3·00	2·84	2·92	14·08	18·5	0·19	2·71
MALMESBURY SLATE.									
Hoogekraal	11,500	7	..	..	..	..	..	..	..
Table Mountain Sandstone, Quartzite, Glencairn Quarry	24,500	16	3·27	2·98	3·13	13·42	19·4	0·19	2·60
Klipheuvel Grit, S. A. R. & H.	8,300	10	..	..	..	..	..	0·41	2·58
Silcrete, Parow (R. H. Morris)	23,300	9	..	..	..	..	..	0·64	2·44

Cape Granite	6,300	9	AVERAGE CRUSHING STRENGTH AND IMPACT VALUES OF MAIN TYPES.
Brackenfel	16,500	11	
Paarl	19,700	12	
Average Granite	18,800	11	
Malmesbury	23,000	28	
Table Mountain Sandstone (Quartzite)	24,500	16	

Attrition Test.

Against 1. Personal factors in selection of aggregate.
2. Large size of apparatus.
3. Long time required for test (8 hours).
4. Cushioning effect leading to anomalies.

For 1. Conditions simulate both impact and abrasion.
2. Very fair correlation with field characters and microscopic structure.

Crushing Test.

Against 1. High cost and large size of apparatus.
2. Stress is purely static and uniform, therefore not comparable to road conditions.
3. Marked effect of shake veins and similar irregularities on result.

For 1. Great rapidity ($\frac{1}{2}$ hour).
2. Very fair correlation with field characters and microscopic structure.

Table III.

Classification Standards.

(According to information from Roads Research Station, West Drayton, London, 1940.)

	Mean Crushing Strength, lb. sq. in.	Impact (No. of Blows).	Attrition, loss per cent.		Abrasion Test Coefficient.	Water Absorption.
			Dry.	Wet.		
Poor . .	7,500	Below 8	over 4	over 5·0	under 15	over 2·0
Rather poor	7,500–15,000	8–12	3·2–4·0	4·1–5·0	15–15·9	2·0–0·60
Fairly good	15,000–25,000	13–15	2·6–3·1	3·2–4·0	16–16·9	0·60–0·25
Good . .	25,000–35,000	16–18	2·1–2·5	2·1–3·1	17–18·9	0·25–0·07
Very good .	above 35,000	19 and over	under 2·0	under 2·0	over 19·0	below 0·07

It will be seen from Table IV that, whatever the method used to assess the relative qualities of the various road stones, the same conclusion is reached in each case. The quantitative data are singularly free from anomalies and those which do occur are capable of explanation. It can be argued, in short, that in the case of the Cape road stones the correlation of field characters, microscopic structure, and physical properties is remarkably good. Incidentally a large proportion of the field and microscopic data had been secured before the testing machines were obtained, and the physical

TABLE IV.

CLASSIFICATION.

Type and Locality of Stone.	Field Date.	Microscopic.	Physical Tests.
GRANITES. Klip Quarry, Cape Flats.	Poor	Poor	Poor
Brackenfel, coarse .	Fair	Fair	Rather poor to fairly good
,, aplitic .	Good	Good	Good
Paarl: Jacobs & Muller . Municipal Quarry N. Paarl Quarry	Fair	Fair	Rather poor to fairly good
Malmesbury: Flaser Rock . .	..	Not desirable for road aggregate	Very doubtful, insufficient data
Microgranite . .	..	Very good	Very good
MALMESBURY. Fairfield Quarry Faure Quarry. Tigerberg (R. H. Morris) . Tigerberg (C. D. C.) De Waal Drive	Good road stones, tendency towards flaky fracture and slaty bands	Good road stone requiring careful selection	Good
Table Mountain Sandstone Quartzite, Glencairn Quarry	Good but requires care in selection to be free from shale and shaly matter	Good	Good
Klipheuvel Grit, S. A. R. & H.	Poor	Poor	Rather poor

properties when determined quantitatively by their means only served to confirm the conclusions previously reached.

Anomalies in Tests.

Klip Granite.—This stone combines high loss by attrition and low crushing strength and impact values with an unexpectedly low loss by abrasion. The reason is to be sought in the mineralogical constitution of the rock. The abundance of large cleavage felspars causes the stone to yield readily on impact and under crushing stresses, and the low values for crushing strength and impact test are thus accounted for. The attrition test shows a considerable loss, for there is a constant impact of the moving

fragments. On the other hand, felspar is a hard mineral and quartz even harder. These two minerals make up about 90 per cent. of the rock, which consequently resists abrasion successfully.

Malmesbury Quartzite.—Examination of the Cape roads shows that the bluestone has distinctly less tendency to part from the bituminous filling than have any of the granites or the Table Mountain quartzite, although the cohesion of road aggregates with bitumen is said to vary roughly with the silica percentage, and this percentage in the granites used is equal to or less than that of the bluestone (Table I, Analysis 5). Their cohesion with bitumen should thus be equal to, or less than, that of the bluestone. The explanation is to be found in the microscopic texture; each clastic grain in the bluestone is coated by biotite, and the freshly fractured rock thus presents a far greater area of biotite than might be expected from the percentage of the mineral. The grains of quartz and felspar evidently have poor adhesion to bitumen, and the very thin films of biotite coating grains in bluestone increase cohesion. Other factors, such as grain size, may, however, be involved, and the question demands further inquiry.

Requirements for Various Methods of Testing Field Characters.

A working knowledge of structural and field geology backed by considerable experience is necessary to assess the qualities of a road aggregate in the field with any certainty.

Microscopic Structure.—To determine the properties of a road stone from its microscopic structure demands, first, facilities for preparing thin sections; second, the use of a good polarising microscope; and third, the mastery of the technique of microscopic petrology. The requirements are more exacting than those for the field method and the apparatus is expensive, though the complete equipment could be obtained at less than half the cost of any single machine required for the physical tests.

Physical Properties.—The equipment necessary for boring and finishing test cylinders is expensive quite apart from the cost of the Dorry abrasion and Page impact and crushing strength machines, but a laboratory so equipped can put the examination of road aggregates on a quantitative basis. Comparisons can thus be made with aggregates from other countries and the personal element is largely eliminated. On the other hand, the selection of suitable samples of the aggregate in the quarry requires both experience and some geological knowledge, particularly in the case of stratified rocks which may show rapid alternations between types of widely differing quality.

Behaviour of Aggregates in Use.—An investigation such as the present one will only be of value if its conclusions are in agreement with the experience

of highway engineers with the aggregates in actual use. Details of road construction are scarcely within the scope of this communication, but it may be observed that, while the Glencairn quartzite (T.M.S.) and Malmesbury bluestones make excellent surfaces on bituminous roads, the Paarl and Brackenfel granites show a certain tendency to crumble and part from the bitumen. This is in accordance with expectations.

7. General Conclusions.

The properties of the three principal types of Cape road stones, viz. (*a*) Granite, (*b*) Argillaceous quartzite (Malmesbury Series), and (*c*) Quartzite (Table Mountain Sandstone Series) were assessed according to their field characters, microscopic petrology, and physical properties determined by standard methods.

The relative suitability of the three types as main road aggregates was determined by all three methods and identical conclusions were reached in each case as follows:—

Argillaceous quartzite (Malmesbury series): very good.
Quartzite (Table Mountain Sandstone series): good.
Granite: fair.
Porphyritic granite: poor.

Further tests showed that fine-grained and micro-granites are equal in quality to the Malmesbury quartzites.

The various test methods are discussed with regard to their rapidity, cost, and ease of operation. It was found impossible to eliminate the personal element entirely particularly in the sampling of material at the quarry face. In this connection the importance of some geological knowledge in those carrying out the tests is strongly emphasised.

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(2) Knight, B. H.—Road Aggregates, their Use and Testing. London, 1935.

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EXPLANATION OF PLATE III.

Photomicrographs × 24. Crossed nicols.

Fig. 1. Granite, Paarl. Consists mainly of large interlocking grains of clear quartz and turbid felspar. A small flake of biotite occupies the bottom left-hand corner.

Fig. 2. Microgranite, 5 miles N. of Malmesbury. The minerals and texture are the same as in fig. 1, but the grain-size is smaller.

Fig. 3. Grit, near Klipheuvel. Large angular to subangular grains of quartz set in an abundant cement consisting of quartz silt and white mica.

Fig. 4. Argillaceous Malmesbury Quartzite, quarry on de Waal Drive, Cape Town. A fine mosaic of quartz and sodic plagioclase felspar as clastic grains fringed by minute flakes of biotite. The sparse cement includes recrystallised argillaceous material and grains of iron ore.

Fig. 5. Quartzite, T.M.S., Glencairn quarry. A medium grained mosaic consisting almost entirely of closely packed quartz grains cemented by silica.

Fig. 1.

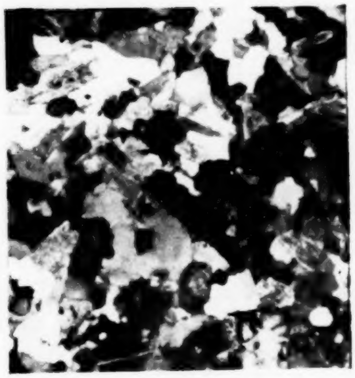

Fig. 2.

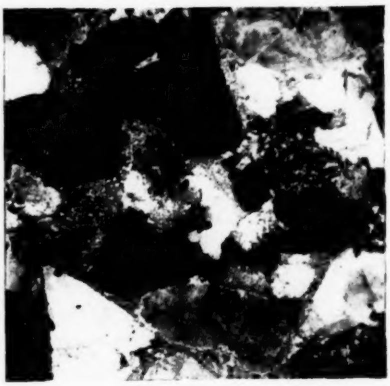

Fig. 3.

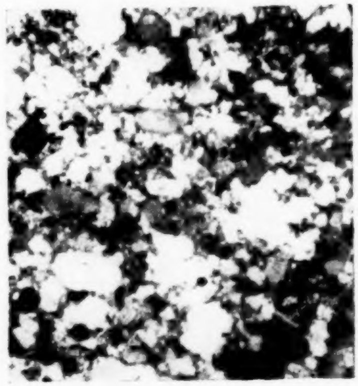

Fig. 4.

Fig. 5.

Walker and Stewart. *Neill & Co., Ltd.*

THE KINETICS OF THE OXIDATION OF ORGANIC COMPOUNDS BY POTASSIUM PERMANGANATE.

Part V: Picric Acid.

By L. M. Hill and F. C. Tompkins.

(With one Text-figure.)

(Read March 17, 1943.)

It has been previously shown (1, 2) that potassium permanganate may oxidise by two different processes, (*a*) by the formation of the intermediate $Mn^{\cdot\cdot\cdot\cdot}$ ion and (*b*) by direct oxidation by the MnO_4' ion. The former mechanism is characterised by an initial induction period, whereas when the latter process is operative, the reaction is kinetically of the second order and the reductant possesses a mobile hydrogen atom. Hinshelwood (3), in a study of the stability of the benzene ring as reflected in the relative rates of oxidation of differently substituted derivatives of phenol, proved that the rate-determining process in the oxidation of picric acid by permanganate was of the second order with a velocity constant of 0·111 g.mols. per litre per sec. at 25° C. Moelwyn-Hughes and Musgrave (4) confirmed these facts and, in addition, obtained a heat of activation of 12,350 cals. at an ionic strength of 0·06 in the temperature range 25°–60° C. The velocity was found to be almost independent of the hydrogen ion concentration, and the salt effect on the bimolecular constant was positive but very small. It was concluded that the one reactant was the picrate ion; the other must therefore be an uncharged particle. The oxidation of the similarly constituted compound 2 : 6 dinitro-phenol (1), however, is of the neutral molecule, and there is found to be an initial induction period, which can be removed by a suitable concentration of manganous ions; this oxidation therefore proceeds by the process (*a*). The oxidation of picric acid appears to be abnormal. It has been suggested that the uncharged reactant in this reaction might be the OH radicle, arising from the reaction of $Mn^{\cdot\cdot\cdot\cdot}$ ions with solvent molecules, but this necessitates an induction period. It was thought that this might have been overlooked in previous work, but its absence has been confirmed here. It thus appears that the oxidation of picric acid takes

place, either by a process different from (*a*) and (*b*), or that the conclusions drawn from the experimental work were erroneous.

Experimental and Discussion.

The iodometric method has been used throughout. The picric acid was of A.R. quality and standardised electrometrically against carbonate-free sodium hydroxide. Aliquots were withdrawn at measured intervals by a special fast-running pipette, calibrated under the experimental conditions of the runs. The accuracy of the withdrawal method had previously been tested in connection with some other work (5). The total acidities were sufficiently low, such that the permanganate reacted solely in the manner $2MnO_4' + 2H^{\cdot} \rightarrow 2MnO_2 + H_2O + 3O$, and since the total strengths of the reactants were always kinetically equivalent and the oxidation was followed over short periods, the oxidation corresponds to $C_6H_3(NO_2)_3OH + 14O \rightarrow 6CO_2 + 3HNO_3$ (4). Throughout all series the ionic strength was maintained constant by the addition of potassium sulphate solution.

In the following, details of experimental work which merely confirmed that of previous workers have been omitted. It may be recorded, however, that the value of the bimolecular constant at 25° C., calculated on a basis of the total picric acid concentration in solution, was 0·109 (Hinshelwood, 0·111; Moelwyn-Hughes, 0·106), and the heat of activation in cals. per g.mol. was 12,200, compared with that of 12,350 cals. at 0·06 ionic strength (Moelwyn-Hughes). Table I gives the results of the effect of variation of

Table I.

10 Ml. $KMnO_4$ (0·1737 M.); 7·5 Ml. Picric Acid (0·02440 M.); Total Volume of 120 Ml. Temperature, 31·40° C.

Time in mins.	Loss of oxidising power of $KMnO_4$ in ml. N thio.			
$2\frac{1}{2}$	0·0131	0·0152	0·0180	0·0231
5	0·0270	0·0312	0·0371	0·0453
10	0·0523	0·0591	0·0620	0·0851
15	0·0753	0·0863	0·0952	0·123
20	0·0961	0·111	0·137	0·155
25	0·115	0·134	0·168	0·185
30	0·128	0·152	0·192	0·210
35	0·139	0·167	0·212	0·229
40	0·148	0·183	0·230	0·240
45	0·158	0·194	0·246	0·259
50	0·164	0·205	0·261	0·271
pH	4·21	2·00	1·41	1·21

the pH of the solution on the initial velocity of oxidation. The former was obtained by the addition of either 0·526 M. sulphuric acid or 0·0987 sodium hydroxide solution and measured by means of a glass electrode. The values given are for zero time obtained by extrapolation.

It is clear that the initial rate of oxidation falls with decrease of hydrogen ion concentration. Calculation of the concentration of the undissociated acid molecules, based on the pH and the classical ionic laws, must necessarily be in the nature of approximations since picric acid is a strong acid with a dissociation constant of $1{\cdot}6 \times 10^{-1}$. Nevertheless, if it ionises in the normal way, and because the ionic strength was held constant, the expression $(H^{\cdot})(P')/(HP) = K$, where (P') is the picrate ion concentration, should give the correct extrapolated result, though the values at higher concentrations will be affected by errors in the assumed value for this constant. The plot of the initial velocity against the picric acid molecule concentration gives a reasonable straight line, but this does not pass through the origin. This cannot be due to the nature of the approximations, which would be reflected only in the slope of the line, but presumably to a secondary mode of oxidation being present. It would therefore suggest that both the acid molecule and the picrate ion are effective in reduction, the effect of the former being roughly twice that of the latter. Such a theory explains the discrepancies found in the work of Moelwyn-Hughes and Musgrave. Their statement (4) that the rate of reaction "is not markedly affected by the amount of sulphuric acid" in solution remains true, but this is because (*a*) a fairly high concentration of this acid is necessary to reduce the ionisation of so strong electrolyte as picric acid, (*b*) both the acid and its ion are oxidised. It is true that fairly good bimolecular constants were calculated (*loc. cit.*) on the assumption that the picrate ion was the only reductant, but this is no confirmation of the nature of the reducing species since an examination shows that such constants decrease regularly from an initial value of 0·123 to one of 0·106 at 275 mins. The explanation of this is now clear. As the oxidation proceeds, the pH of the solution increases on account of the production of nitric acid. The concentration of the neutral picric acid molecules therefore decreases more rapidly than that of the total concentration of picric acid, which is calculated at any time from the loss of oxidising power of the permanganate. Since the specific reducing action of the neutral molecule is about twice that of the picrate ion, the measured overall velocity will fall. In the same way, the falling off of the velocity constants should be relatively larger in oxidations proceeding in absence of sulphuric acid—their figures thus show an initial value of 0·103, decreasing to 0·076. This variation emphasises that only initial velocities, or velocity constants extrapolated to zero time, can have any true significance in such a complex oxidation.

The neutral salt effect has been re-examined, but over a 300 per cent. increase in the ionic strength merely caused an increase of less than 20 per cent. in the velocity constants. This increase, although fairly substantial since the ionic strengths were above the region in which the Debye-Hückel equation is applicable, is much smaller than that to be expected on the theory that both reactants are singly charged ions of the same sign. It

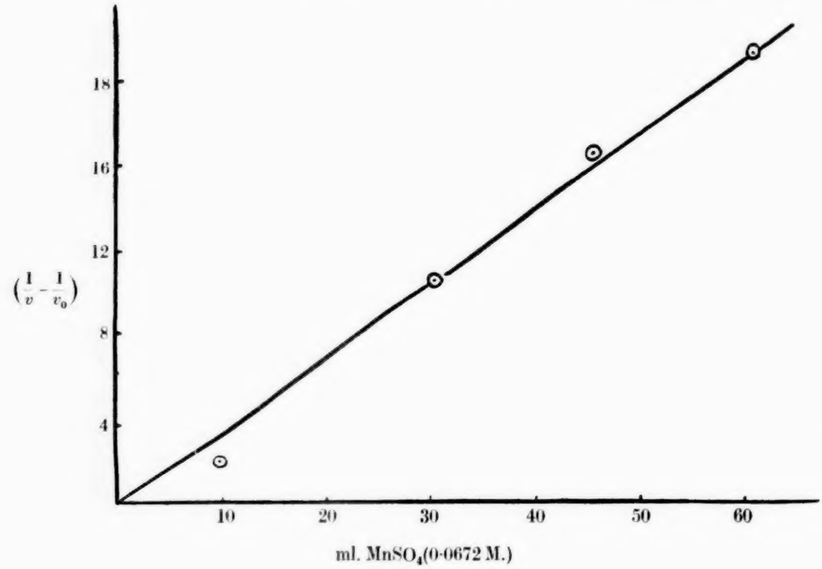

FIG. 1.

v is the initial vel. in arbitrary units (ml. 0·1213 N. thio. per min.) in presence of $MnSO_4$; v_0 is the initial vel in the same units in absence of $MnSO_4$.
10 ml. $KMnO_4$ (0·0867 M.); 7·5 ml. picric acid (0·01830 M.).
40 ml. sulphuric acid (0·0526 M.); $MnSO_4$ (0·0672 M.).
Total volume 120 ml. Temperature 31·40° C.

would therefore again suggest that the one reactant is to some extent an uncharged particle, *i.e.* the picric acid molecule. The actual rise in velocity is adequately accounted for by the less predominant oxidation, that of the picrate ion. To preserve the second order character, the other reactant must be the permanganate ion as in the oxidation of the formate ion. In Part III of this series (2), it has been shown that the addition of manganous ions causes a retardation such that the plot of $(1/v-1/v_0)$ against the concentration of these ions is a straight line, if the MnO_4' ion directly oxidises.

Fig. 1 summarises the results and confirms that this ion is the second reactant. Taken in conjunction with the neutral salt effect, it is some proof that the neutral picric acid molecule and the picrate ion are both effective in reducing the permanganate ion. The general oxidation therefore proceeds according to the mechanism (*b*).

The application of molecular statistics to the reaction again leads to no unambiguous conclusion. Moelwyn-Hughes and Musgrave have assumed that the two reactants are the picrate and permanganate ion (a theory which is at variance with their results on the effect of neutral salts), and found that ternary collisions with solvent molecules would lead to a calculated rate which was thirty times greater than the experimental value. A recalculation based on the approximate concentration of the picric acid molecule does not distinguish between the possibility of bimolecular or ternary collisions. The reduction in collision number, however, does suggest that the reaction with the neutral molecule is bimolecular, but that simultaneously there is an oxidation of the picrate ion by ternary collisions with the solvent molecules. In the latter case, a molecule of water may become the bridge linking the two reactant ions in the form of a complex, which subsequently decomposes with the liberation of the OH′ ion and a water molecule, a process which is not unlike that suggested in the mechanism (*b*).

It appears evident that the results of former work (4) and those obtained here are more in accord with the theory that both the molecule and its anion are simultaneously oxidised by the permanganate ion, the specific reducing effect of the former being about twice that of the latter. This accounts for (*a*) the small but linear variation of rate with hydrogen ion concentration, (*b*) the positive but small effect of neutral salts, (*c*) the linear retardation effect of manganous ions, (*d*) the discrepancy of calculated and observed rate, (*e*) the decrease in velocity constants with time when these are calculated on the basis of the total picric acid concentration.

Summary.

The oxidation of picric acid by potassium permanganate in aqueous solution has been re-examined. The experimental results are in good agreement with those obtained previously, but it is shown that erroneous conclusions had been made. A new interpretation is proposed which correlates with the previous oxidations studied in this series and also accounts for the apparent discrepancies found in previous work.

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CURVE FITTING BY MEANS OF THE ORTHOGONAL POLYNOMIALS IN BINOMIAL STATISTICAL DISTRIBUTIONS.

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(Read March 17, 1943.)

The polynomials which we wish to use in our curve fitting have the following property, namely:—

$$\sum_{0}^{n} G_r(x)G_s(x)\phi(x) = 0, \qquad r \neq s = r!\ n^{(r)}p^r q^r, \qquad r = s > 0,$$

where $\phi(x)$ is the well-known binomial frequency function $\binom{n}{x}p^x q^{n-x}$, which arises under simple sampling n times with replacement.

These polynomials were first studied by Aitken and Gonin (1) in 1935. Gram (2) and Greenleaf (3), considering the symmetrical binomial associated with $(\frac{1}{2}+\frac{1}{2})^n$, when n is even, obtained the special case of these polynomials in which $p=\frac{1}{2}$.

The standard form obtained by Aitken and Gonin was:

(A) $$G_r(x) = (-1)^r\{-p^r{}_n{}^{(r)} - (n-1)^{(r-1)}rp^{r-1}x_{(1)} + (n-2)^{(r-2)}r^{(2)}p^{r-2}x_{(2)} + \dots + r!\ x_{(r)}\},$$

where $$x_{(r)} = \frac{x^{(r)}}{r!}$$

and $$x^{(r)} = x(x-1)\dots(x-r+1).$$

Now the form (A) may be written as:

(B) $G_r(x) = b_0 + b_1 x_{(1)} + \dots + b_r x_{(r)}$.

Let θ_x be the observed frequencies of a series of data. Multiply (B) by θ_x and sum over all values of x and we obtain

$$\Sigma\theta_x G_r(x) = b_0\Sigma\theta_x + b_1\Sigma\theta_x x_{(1)} + \dots + b_r\Sigma\theta_x x_{(r)}.$$

Therefore

(C) $$\Sigma\theta_x G_r(x) = b_0 m_{(0)} + b_1 m_{(1)} + \dots + b_r m_{(r)},$$

where $m_{(r)} = \Sigma\theta_x x_{(r)}$, the r^{th} reduced factorial moment of the data.

Now (A) is really a Gregory-Newton interpolation formula. Hence the coefficients of $1, x_{(1)} \dots x_{(r)}$, are the terminal values $G_r(0), \Delta G_r(0), \dots \Delta^r G_r(0)$.

Greenleaf (3) in 1932 in a paper used the symmetrical polynomials in

which $p=\frac{1}{2}$ and n is even to fit a series of data by the method of least squares. This method can, however, be greatly improved. In this paper we wish to show how the compact tabular method devised by Aitken (4) can be applied in Greenleaf's special case as well as in the case of the more general binomial polynomials.

Let us fit a series of observed frequencies θ_x to the curve

$$Yx=\{a_0G_0(x)+a_1G_1(x)+\ .\ .\ .\ a_rG_r(x)\}\phi(x),$$

where $\phi(x)=\binom{n}{x}p^xq^{n-x}$.

Following Greenleaf, we choose the reciprocal of $\phi(x)$ to give us a weighting system.

By Legendre's principle,

$$S^2=\Sigma\phi(x)^{-1}[\theta_x-\{a_0G_0(x)+a_1G_1(x)+\ .\ .\ .\ +a_rG_r(x)\}\phi(x)]^2$$

must be a minimum.

$$\therefore\ \frac{\partial S^2}{\partial a_r}=0.$$

Using the orthogonal properties of the polynomials we have:

$$\Sigma\theta_xG_r(x)=a_r\Sigma\phi(x)G_r^2(x)=r!\ n^{(r)}p^rq^r.$$

$\therefore$ From (C) we have that:

$$a_r\Sigma\phi(x)G_r^2(x)=b_0+b_1m_{(1)}+\ .\ .\ .\ b_rm_{(r)}.$$

Hence the a_rs can be computed by combining the various coefficients of $1, x_{(1)}\ .\ .\ .\ x_{(r)}$ of our polynomials, with the reduced factorial moments of the observed frequencies and dividing by $\Sigma\phi(x)G_r^2(x)$.

Again we have that:

$$\begin{cases} Y_0/\phi(0)=a_0+a_1G_1(0)+a_2G_2(0)+\ .\ .\ .\ a_rG_r(0) \\ \Delta Y_0/\phi(0)=a_1\Delta G_1(0)+a_2\Delta G_2(0)+\ .\ .\ .\ a_r\Delta G_r(0) \\ \Delta^rY_0/\phi(0)=a_r\Delta^rG_r(0). \end{cases}$$

hat is:

$$\begin{cases} Y_0/\phi(0)=a_0+a_1b_0+a_2b_0+\ .\ .\ .\ a_rb_0 \\ \Delta Y_0/\phi(0)=a_1b_1+a_2b_1+\ .\ .\ .\ a_rb_1 \\ \Delta^rY_0/\phi(0)=a_rb_r. \end{cases}$$

The whole graduation therefore falls into four easy steps—(1) compute the reduced factorial moments; (2) combine these according to multipliers in the *columns* of terminal values and differences of $Gr(x)$, which we shall set forth; (3) combine these a_rs obtained by step (2) according to multipliers in the *rows* of the same table, thus obtaining $Y_0/\phi(0)$, $\Delta Y_0/\phi(0)$, . . ., $\Delta^rY_0/\phi(0)$; (4) the other graduated values can then be built up by summa-

tion. We shall graduate the same data as Greenleaf, putting $n=2m$ and $p=\frac{1}{2}$.

The following formulae are used:—

$$\begin{cases} Gr(0)=(-1)^r(2m)^{(r)}/2^r. \\ \Delta G_r(0)=(-1)^{r-1}r(2m-1)^{(r-1)}/2^{r-1}. \\ \Delta^r G_r(0)=r! \\ \Sigma\phi(x)G_r^2(x)=r!\ (2m)^{(r)}/2^{2r}. \end{cases}$$

The reduced factorial moments are calculated in the usual way, by repeated summation from the feet of columns.

θ_x.	$\hat{\Sigma}$.	$\hat{\Sigma}^2$.	$\hat{\Sigma}^3$.	$\hat{\Sigma}^4$.	$\hat{\Sigma}^5$.	$\hat{\Sigma}^6$.	$\hat{\Sigma}^7$.
0	**500**						
0	500	**3430**					
3	500	2930	**11089**				
7	497	2430	8159	**22760**			
35	490	1933	5729	14601	**33667**		
101	455	1443	3796	8872	19066	**38420**	
89	354	988	2353	5076	10194	19354	**35080**
94	265	634	1365	2723	5118	9160	15726
70	171	369	731	1358	2395	4042	6566
46	101	198	362	627	1037	1647	2524
30	55	97	164	265	410	610	877
15	25	42	67	101	145	200	267
4	10	17	25	34	44	55	67
5	6	7	8	9	10	11	12
1	1	1	1	1	1	1	1

	$a_r{}^s$.						
r.	0.	1.	2.	3.	4.	5.	6.
	500.	−20.	14·85714.	10·57875.	1·21744.	·35964.	·18056.
500 $G(0)$	1	−7	45·5	−273	1501·5	−7507·5	33783·75
3430 $\Delta G(0)$		1	−13	117	−858	5362·5	−28957·5
$m_r{}^s$ 11089 $\Delta^2 G(0)$			2	−36	396	−3300	22275
22760 $\Delta^3 G(0)$				6	−132	1650	−14850
33667 $\Delta^4 G(0)$					24	−600	8100
38420 $\Delta^5 G(0)$						120	−3240
35080 $\Delta^6 G(0)$							720
$\Sigma\phi(x)G_r^2(x)$	1	3·5	22·75	204·75	2252·25	28153·125	380067

e.g. $a_5=\{500\times(-7507{\cdot}5)+3430\times(5362{\cdot}5)+11089\times(-3300)$
$+22760\times(1650)+33667\times(-600)+38420\times(120)\}\div 28153{\cdot}125$
$=\cdot 35964.$

The a_r's are the same as Greenleaf's except a_5, for which he gets ·39564, evidently copied down wrongly.

We shall put $a_5 = \cdot 39564$ for the time being in order to check Greenleaf's results.

The next step is the combining of the a_r's with the multipliers in the *rows* to get $Y_0/\phi(0), \Delta Y_0/\phi(0), \Delta^2 Y_0/\phi(0)$.

e.g. $\Delta^2 Y_0/\phi(0) = 14{\cdot}85714 \times (2) + 10{\cdot}57875 \times (-36) + 1{\cdot}21744 \times (396)$
$+ \cdot 39564(-3300) + \cdot 18056 \times (22275)$
$= 2847{\cdot}348.$

The following results are obtained for $a_5 = \cdot 39564$:—

$Y_0/\phi(0)$.	$\Delta Y_0/\phi(0)$.	$\Delta^2 Y_0/\phi(0)$.	$\Delta^3 Y_0/\phi(0)$.	$\Delta^4 Y_0/\phi(0)$.	$\Delta^5 Y_0/\phi(0)$.	$\Delta^6 Y_0/\phi(0)$.
3385·714	−3126·939	2847·348	−2125·740	1254·371	−537·538	130·003

From these terminal values the difference table is easily completed. We give the difference table for the corrected $a_5 = \cdot 35964$.

$Y_0/\phi(0)$.	Δ.	Δ^2.	Δ^3.	Δ^4.	Δ^5.	Δ^6.
3655·984	−3319·989	2966·147	−2185·139	1275·971	−541·857	130·0032
335·995	−353·842	781·008	−909·168	734·114	−411·854	
−17·847	427·166	−128·160	−175·054	322·260	−281·851	
409·319	299·006	−303·214	147·206	40·409	−151·847	
708·325	−4·208	−156·008	187·615	−111·438	−21·844	
704·117	−160·216	31·607	76·177	−133·282	108·159	
543·901	−128·609	107·784	−57·105	−25·123	238·162	
415·292	−20·825	50·679	−82·228	213·039	368·165	
394·467	29·854	−31·549	130·811	581·204	498·168	
424·321	−1·695	99·262	712·015	1079·372	628·171	
422·626	97·567	811·277	1791·387	1707·543		
520·193	908·844	2602·664	3498·930			
1429·037	3511·508	6101·594				
4940·545	9613·102					
14553·647						

The following results are obtained for $Y_x/\phi(x)$:—

x.	0.	1.	2.	3.	4.	5.	6.	7.
$Y_x/\phi(x)$ . .	3386	259	−21	421	713	701	540	415
$Y_x/\phi(x)$ . . (corrected a_5)	3656	336	−18	409	708	704	544	415

x.	8.	9.	10.	11.	12.	13.	14.
$Y_x/\phi(x)$ . .	398	427	417	508	1431	5016	14822
$Y_x/\phi(x)$ . . (corrected a_5)	394	424	423	520	1429	4941	14554

Terminal Check on the Whole Calculation.

$$Y_{14}/\phi(14) = a_0G_0(0) - a_1G_1(0) + a_2G_2(0) - a_3G_3(0) + a_4G_4(0) - a_5G_5(0) + a_6G_6(0)$$
$$= 14552. \quad \text{(Against 14554 by the difference table.)}$$

Graduation by Means of Central and Mean Central Factorial Moments.

If the data is even, we multiply each datum θ_x by the corresponding value of the reduced central or reduced mean central factorial polynomials of appropriate degree which appear in the Newton-Bessel formula, and sum over all values. Thus the values of x are here $\pm\frac{1}{2}, \pm\frac{3}{2}, \pm\frac{5}{2}, \ldots$, etc.

On the other hand, *if the number of data is odd*, we shall use the values of the Newton-Stirling formula, the values of x then being $0, \pm 1, \pm 2, \ldots$

Definition of Central Factorials.

Let $x^{\{r\}}$ denote the central factorial,

then $$x^{\{r\}} = (x + \tfrac{1}{2}r - 1)^{(r)}$$

i.e. $$x^{\{2s+1\}} = x(x^2 - 1)(x^2 - 4) \ldots (x^2 - s^2).$$

Let $x_{\{r\}}$ denote the reduced central factorial,

then $$x_{\{r\}} = \frac{x^{\{r\}}}{r!},$$

e.g. $$x_{\{5\}} = \frac{x(x^2 - 1)(x^2 - 4)}{5!}.$$

Definition of Mean Central Factorials.

We denote the mean central factorial by $\mu x^{\{r\}}$,

where $$\mu x^{\{r\}} = x^{\{r-1\}}x = x^{\{r-1\}+1},$$

e.g. $$\mu x^{\{4\}} = x^{\{3\}}x = x^2(x^2 - 1),$$

and $$\mu x_{\{4\}} = \frac{x^2(x^2 - 1)}{4!}.$$

We shall now graduate Greenleaf's odd set of data by making use of these central and mean central factorial polynomials.

Greenleaf's polynomials are first written in central form. These polynomials, when all measures of x are transferred to the mean m as origin, may be written in the following form with central factorials (Aitken and Gonin (1)):—

$$\hat{G}_0(x) = 1, \qquad \hat{G}_1(x) = x, \qquad \hat{G}_2(x) = 2!\frac{x^2}{2} - \frac{m}{2}.$$

$$\hat{G}_3(x) = 3!\,\frac{x(x^2-1)}{3!} - \frac{3}{2}(m-1)x.$$

$$\hat{G}_4(x) = 4!\,\frac{x^2(x^2-1)}{4!} - 6(m-1)\frac{x^2}{2} + \frac{3}{4}m(m-1).$$

$$\hat{G}_5(x) = 5!\,\frac{x(x^2-1)(x^2-4)}{5!} - 30(m-2)\frac{x(x^2-1)}{3!} + \frac{15}{4}(m-1)(m-2)x.$$

$$\hat{G}_6(x) = 6!\frac{x^2(x^2-1)(x^2-4)}{6!} - 180(m-2)\frac{x^2(x^2-1)}{4!} + \frac{45}{2}(m-1)(m-2)\frac{x^2}{2} - \frac{15}{8}(m)(m-1)(m-2).$$

The factorials,

$$x, \quad \frac{x^2}{2!}, \quad \frac{x(x^2-1)}{3!}, \quad \frac{x^2(x^2-1)}{4!}, \quad \frac{x(x^2-1)(x^2-4)}{5!},$$

are either reduced central or reduced mean central factorials and are exactly those that occur in the Newton-Stirling interpolation formula:

$$f_x = f_0 + x\mu\delta f_0 + \frac{x^2}{2!}\delta^2 f_0 + \frac{x(x^2-1)}{3!}\mu\delta^3 f_0 + \frac{x^2(x^2-1)}{4!}\delta^4 f_0 + \ldots$$

Let us denote the reduced central and reduced mean central factorial moments by $m_{\{r\}}$ and $m_{\{r\}}' = \mu m_{\{r\}}$ respectively. These are readily obtained by processes of repeated summation from the outer termini towards the centre (Aitken) (4). Following Dr. Aitken we break up the graduated function $Y_x/\phi(x)$ into an even function V_x and an odd function W_x, with the obvious consequences that the values of $Y_0/\phi(0)$ or $\mu Y_0/\phi(0)$, and its central differences of an even order are the same as those of V_0 or μV_0, and its central differences of odd order are the same as those of W_0 or μW_0. The symmetry or alteration of even and odd function and their differences about the central origin then enables us to complete the solution in a very simple manner. The numerical graduation will clearly illustrate these points.

Computation of Necessary Moments.

x.	θ_x.	$\mu\hat{\Sigma}$.	$\hat{\Sigma}^2$.	$\mu\hat{\Sigma}^3$.	$\hat{\Sigma}^4$.	$\mu\hat{\Sigma}^5$.	$\hat{\Sigma}^6$.	$\mu\hat{\Sigma}^7$.
−7	0	0	0	0	0	0	0	0
−6	0	0	0	0	0	0	0	0
−5	3	3	3	3	3	3	3	3
−4	7	10	13	16	19	22	25	28
								(98)
−3	35	45	58	74	93	115	140	
						(300·5)		
−2	101	146	204	278	371			
				(497·5)				
−1	89	235	439					
		(282)						
0	94							
		(218)						
1	70	171	369					
				(546·5)				
2	46	101	198	362	627			
						(723·5)		
3	30	55	97	164	265	410	610	
								(572)
4	15	25	42	67	101	145	200	267
5	4	10	17	25	34	44	55	67
6	5	6	7	8	9	10	11	12
7	1	1	1	1	1	1	1	1

$m_{\{0\}'}=500.$ $\quad m_{\{4\}'}=1024.$

$m_{\{1\}}=439-369=70.$ $\quad m_{\{5\}}=-470.$

$m_{\{2\}'}=1044.$ $\quad m_{\{6\}'}=670.$

$m_{\{3\}}=-256.$

$2m=14$, i.e. $m=7$.

r.		0.	1.	2.	3.	4.	5.	6.
a_r^2.		500.	20.	14·85714.	−10·57875.	1·21744.	−·35964.	·18056.
$\hat{G}(0)$	500	1	.	−3·5	.	31·5	.	−393·75
$\mu\delta\hat{G}(0)$	70		1	.	−9	.	112·5	.
$\delta^2\hat{G}(0)$	1044			2	.	−36	.	675
$\mu\delta^3\hat{G}(0)$	−256				6	.	−150	.
$\delta^4\hat{G}(0)$	1024					24	.	−900
$\mu\delta^5\hat{G}(0)$	−470						120	.
$\delta^6\hat{G}(0)$	670							720
$\Sigma\phi(x)G_r^2(x)$		1	3·5	22·75	204·75	2252·25	28153·125	380067

$V_0=415·2539.$ $\quad \delta^4 V_0=-133·2854.$

$\mu\delta W_0=74·7492.$ $\quad \mu\delta^5 W_0=-43·1568.$

$\delta^2 V_0=107·7644.$ $\quad \delta^6 V_0=130·0032.$

$\mu\delta^3 W_0=-9·5265.$

Hence by completing the two difference tables we obtain the following values for V and W (V and W are defined in Dr. Aitken's paper (4).)

$x =$	0.	1.	2.	3.	4.	5.	6.	7.
$V =$	415	469	564	565	465	705	2638	9104
$W =$	0	75	140	143	− 55	− 723	− 2302	− 5448

x.	V.	δV.	$\delta^2 V$.	$\delta^3 V$.	$\delta^4 V$.	$\delta^5 V$.	$\delta^6 V$.
0	415·2539	− 53·8822	107·7644	66·6427	− 133·2854	− 65·0016	130·0032
1	469·1361	53·8822	41·1217	− 66·6427	− 68·2838	65·0016	130·0032
2	564·1400	95·0039	− 93·8048	− 134·9265	126·7210	195·0048	130·0032
3	565·3391	1·1991	− 102·0103	− 8·2055	451·7290	325·0080	130·0032
4	464·5279	− 100·8112	341·5132	443·5235	906·7402	455·0112	130·0032
5	705·2299	240·7020	1691·7769	1350·2637	1491·7546	585·0144	
6	2637·7088	1932·4789	4533·7952	2842·0183			
7	9103·9829	6466·2741					

x.	W.	δW.	$\delta^2 W$.	$\delta^3 W$.	$\delta^4 W$.	$\delta^5 W$.
0		74·7492	0	− 9·5265	0	− 43·1568
1	74·7492	65·2227	− 9·5265	− 52·6833	− 43·1568	− 43·1568
2	139·9719	3·0129	− 62·2098	− 138·9969	− 86·3136	− 43·1568
3	142·9848	− 198·1938	− 201·2067	− 268·4673	− 129·4704	− 43·1568
4	− 55·2090	− 667·8678	− 469·6740	− 441·0945	− 172·6272	− 43·1568
5	− 723·0768	− 1578·6363	− 910·7685	− 656·8785	− 215·7840	
6	− 2301·7131	− 3146·2833	− 1567·6470			
7	− 5447·9964					

Now $V + W$ and $V - W$ will give us the graduated values. [See Aitken (4).]

We obtain:

$V + W$	415	544	704	708	409	− 18	336	3656
$V - W$	415	394	424	422	520	1428	4939	14552

In this case we have to dispense with the terminal check.

Hence we obtain the following results:—

Under (*a*) we used reduced central and mean central factorial moments.

Under (*b*) we used ordinary reduced factorial moments.

(a) $Y_x/\phi(x)$.	(b) $Y_x/\phi(x)$ (earlier method).	Hence from (a) and (b) Y_x.	θ_x (observed).
3656	3656	0	0
336	336	0	0
−18	−18	0	3
409	409	9	7
708	708	44	35
704	704	86	101
544	544	99	89
415	415	87	94
394	394	73	70
424	424	52	46
422	423	26	30
520	520	11	15
1428	1429	8	4
4939	4941	4	5
14552	14554	1	1

We can fit any set of data to a polynomial of the rth degree by the method of least squares, using the general binomial polynomials and with weighting function:

$$[v_x]^{-1} = \left[\binom{n}{x} p^x q^{n-x}\right]^{-1}.$$

The choice of the set of weights is arrived at by the same argument which gives the terms of Pearson's χ^2 and the parameters p and n allow flexibility in approximating to any given weights. A method with weights given, but subject to no law, would be highly laborious.

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THE DEVELOPMENT OF THE ARTERIAL SYSTEM OF *XENOPUS LAEVIS*, INCLUDING EXPERIMENTS ON THE DESTRUCTION OF THE LARVAL AORTIC ARCHES.

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(With Plates IV–VIII.)

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CONTENTS.

Introduction.

The development of the aortic arches of *Rana esculenta* has been described in detail by Maurer (1888) and Boas (1882). Descriptions also exist of the development of *Bombinator igneus* (Goette, 1875) and *Rana temporaria* (Marshall and Bles, 1890), but the author was unable to obtain access to these works and their context had to be gathered from quotations by other authors. Very little has been done on the development of the blood vessels in the Aglossa, which should be particularly interesting, since in *Xenopus* there are no internal gills but a remarkably well-developed and complex filter apparatus, which serves as a feeding and probably also as a respiratory mechanism.

Nikitin (1925) drew attention to some of the important points, but did not touch on the younger stages. Recently Paterson (1942) published a brief description of the development in *Xenopus*, but again failing to use

young enough material, she did not observe the presence of the first and second aortic arches. Moreover, her description of the development of the fourth aortic arch was found to be incorrect It was accordingly thought worth while to publish a more complete and detailed description.

The experiments on the destruction of the aortic arches in the tadpole stage were suggested by the work of Figge (1930 and 1934) on Urodeles, and serve in the first place as a check on some of the conclusions reached in the first part of this paper, and in the second place as an interesting connection with an abnormality described in a previous paper (Millard, 1942).

Material and Technique.

The entire work was based on the study of serial sections, and all diagrams (except Pl. VIII, fig. 2) are reconstructions made by means of a Leitz "Panphot."

Difficulty was experienced in obtaining the younger stages in the free state, so a number of adults were induced to reproduce in the laboratory by injecting them with pituitary extract. The eggs were then reared and fixed at various stages of development. Sublimate formol was used as a fixative and all measurements (from snout to end of tail) were made before fixation. Various stains were tried, but the most satisfactory were found to be (i) bulk-staining with borax-carmine and counterstaining with azan, and (ii) bulk-staining with haemalum and Bismarck brown and counter-staining with acid fuchsin.

Development of the Arterial System.

First Stage.

The first rudiments of heart and aortic arches are found in embryos 4 mm. in length, which have not yet escaped from the egg membrane. Three such embryos were sectioned and represent slightly different stages of development.

In the youngest there is no differentiation of heart or development of arteries. In a slightly older stage the heart is present below the gut as a simple, undivided tube and the first pair of aortic arches is already laid down. Each arch arises from the anterior end of the heart and runs forwards below the gut close to the mid-line. After a short distance it turns slightly outwards, and then continues forwards through the ventral portion of the lateral plate mesoderm past the region of the hyoid arch until it reaches the mandibular arch, where it turns dorsally round the gut. Above the gut it bends backwards and ends blindly. In parts this artery is poorly developed and possesses no wall, being merely a slit among the mesenchyme cells. It is, however, perfectly continuous throughout.

In the oldest 4-mm. embryo this first aortic arch is joined in the dorsal region of the mandibular arch by a short internal carotid artery. Then it extends backwards as far as the region of the spiracle as the paired dorsal aorta.

The course of the first aortic arch is similar to that described by Maurer (1888) for *Rana esculenta*. Since it traverses the ventral region of the hyoid arch he calls it the "Arteria hyo-mandibularis." In *Xenopus* it is laid down before any of the other aortic arches and simultaneously with the formation of the heart.

Second Stage.

At 5 mm. the embryos have just hatched, and again three specimens at slightly different stages were sectioned.

In the youngest there is little further development. No further aortic arches have appeared, and the course of the first arch is similar to that already described. The paired dorsal aorta, however, now extends back as far as the region of the third branchial arch, and the heart gives off a small pouch on each side posterior to the origin of the first arch—the beginning of the posterior arches.

At an older stage, considerable further developments have taken place (see Pl. IV, fig. 1). As yet the gut is not open to the exterior, and none of the gill slits have broken through, although the rudiments of the first, second, third, and fourth pairs and also the spiracles are easily recognisable.* By now three pairs of aortic arches are present and complete, namely the first, third, and fourth, while small dorsal portions of the second and fifth can also be seen entering the paired dorsal aortae.

The first aortic arch, as before, leaves the heart ventrally and joins the paired dorsal aorta dorsally in the region of the mandibular arch. Its lumen is enclosed in a thin wall throughout its course.

The second aortic or hyoid arch is represented by a minute blind vessel entering the paired dorsal aorta immediately next to the third arch. It is obviously only a vestige and entirely without function. It has been observed only in 5-mm. and 6-mm. embryos, after which it vanishes completely.

* At first these rudiments are merely proliferations of the gut endoderm which are clearly displayed by certain stains (*e.g.* azan). Later pouches grow out from the gut into these masses of cells, and finally, in those gill slits which do break through, these evaginations of the gut endoderm meet similar, but smaller, invaginations of the ectoderm. The first gill slit thus to open to the exterior is the second (in 6·5-mm. embryos), and the third and fourth pairs acquire their openings soon after (8-mm. embryos). The spiracle and first gill slit never acquire openings, although their endodermal evaginations are distinct in the early stages. The rudiment of the fifth gill slit is very poorly developed and is never more than a proliferation of cells (see Pl. VI).

The third and fourth aortic arches leave the heart together but immediately separate. The third arch runs outwards into the first branchial arch. Here it splits into two vessels—an anterior and a posterior—which turn dorsally round the gut and join again about half-way round. The aortic arch then continues dorsally to join the paired dorsal aorta.

The fourth aortic arch passes into the second branchial arch and splits into two in an exactly similar manner. Again the two branches join half-way round the gut and the aortic arch continues dorsally to join the paired dorsal aorta.

At this stage the beginning of the fifth aortic arch is visible as a minute dorsal stump entering the paired dorsal aorta immediately behind the fourth arch. Of its ventral connection with the heart, however, there is no sign. The paired dorsal aorta continues backwards beyond the junction of this arch to join its fellow in the mid-line and form the median aorta. The latter ends blindly slightly further back.

In the oldest 5-mm. embryo external gills are just starting to develop on the first and second branchial arches, but as yet the structure of the third and fourth aortic arches is unchanged. The fifth aortic arch now extends ventrally round the gut and is connected with the fourth arch in the ventral region by a slit-like cavity among the mesenchyme cells. For the first time corpuscles are present in the heart and arches.

It is difficult to determine the exact manner in which the first, third, and fourth aortic arches are laid down because of the suddenness of their appearance. Considering the structure of the first arch, however, in its earliest stages, where in parts it lacks a wall altogether, it appears that it is laid down in a similar manner to the third and fourth aortic arches of *Rana esculenta* (Maurer, 1888) from "unregelmässige Spaltenbildungen im embryonalen Bindegewebe." It is reasonable to assume that the third and fourth arches have a similar origin, especially since in their earliest stages the lumen has a sinuous appearance due to the bulging in of the surrounding cells. The fifth arch appears to arise as an outgrowth of the paired dorsal aorta which proceeds ventrally until finally its ventral end becomes connected with the arch in front by a slit-like passage through the mesenchyme cells.

Of the two branches of the third and fourth aortic arches the posterior in both cases is destined to supply an external gill and is obviously homologous with the secondary vessel of Maurer, while the anterior is the primary vessel. Maurer states that in *Rana esculenta* the primary vessel appears first, and the secondary vessel arises from the heart and grows out behind the primary to join it again in the region of the gill rudiment. In the Urodeles (e.g. *Triton taeniatus*) primary and secondary vessels appear at the same time, although the ventral connection between the two vessels

is not established until a later stage. In *Xenopus* the two vessels arise simultaneously, and from the very earliest stage both ventral and dorsal communications are established.

Third Stage (Pl. IV, fig. 2; Pl. VII, figs. 1–4).

In 6-mm. embryos external gills are present on the first and second branchial arches. These external gills have already been correctly described by Beddard (1894); they are simple, backwardly projecting lamellae borne on the first two branchial arches only and never acquiring the size or complexity of the corresponding arborescent structures of *Rana*. Occasionally in the author's experience one or more of the external gills may be double. In these cases the original external gill appears to branch from its base, forming a second lamella shorter than the original one and medial to it (*cf.* Pl. IV, fig. 3). This is probably what has caused Peter (1930) to state that there are three pairs of external gills in *Xenopus* larvae.

The external gills are supplied by the secondary vessels of the third and fourth aortic arches which now bend backwards to form loops projecting into the bases of the gills (Pl. IV, fig. 2). The secondary vessel of the third arch is better developed than that of the fourth and has acquired an extra anastomosis between the afferent part of the loop and the primary vessel.

The fifth aortic arch at this stage is complete. It possesses no secondary vessel, but separates from the fourth arch ventrally, passes dorsally round the third branchial arch and joins the paired dorsal aorta just behind the fourth aortic arch.

The sixth aortic arch as such is not yet present, although in one embryo its dorsal end could be seen entering the paired dorsal aorta on one side. Its future position is indicated by small irregular splits in the mesenchyme.

The first and second arches are now beginning to degenerate, and it seems a suitable time to discuss their fate. The second or hyoid arch is present in some 6-mm. embryos, while in others it has already disappeared. This arch then, which in *Xenopus* is never more than a blind stump and which disappears almost immediately after it is laid down, is only the vestige of an aortic arch once functional in lower forms. Marshall and Bles (1890) are quoted to have described a similar vestige in *Rana temporaria*, and Goette (1875) has described what he calls a hyoid artery in *Bombinator igneus*, but Maurer was unable to find any sign of a second aortic arch in *Rana esculenta*.

The first part of the first aortic arch to break down is the anterior ventral portion (see Pl. IV, fig. 2). The ventral posterior portion maintains its connexion with the third aortic arch and forms part of the external carotid artery. The lateral portion of the arch (that part passing dorsally round the gut) disappears by the 7-mm. stage. The dorsal portion, joining the

paired dorsal aorta, persists in *Xenopus* as the proximal end of the posterior palatine artery of the embryo, which after metamorphosis forms the arteria palatina of the adult. The course of this artery during larval life has already been described by Paterson (1939). It leaves the internal carotid artery and runs diagonally forwards and outwards, crossing the subocular fenestra and subocular bar of the palatoquadrate ventrally. It runs forwards along the outer edge of the latter for a short distance, then passes on to the dorsal surface of the processus muscularis where it supplies the levator hyoideus muscle, and continues forwards to the outer region of the nasal capsule. In later embryos it supplies the tentacle with a large branch and also other muscles (levator mandibulae anterior, levator mandibulae posterior). After metamorphosis it assumes the characteristic course of the a. palatina.

It may be mentioned here that there is also an anterior palatine artery in the embryo, which during metamorphosis gradually loses its importance and disappears. The branches of the internal carotid artery, after receiving the first aortic arch, are as follows (in 6-mm. embryos):—

(*a*) The anterior palatine artery, which crosses the optic nerve ventrally and runs straight forwards above the gut to the region of the stomodaeum where it supplies the inner surface of the developing nasal organ;

(*b*) The ophthalmic artery, which passes directly out to the eye close to the optic nerve; and

(*c*) The arteria carotis cerebralis which passes dorsalwards to the brain between the eye and the infundibulum.

In later embryos the course of the anterior palatine artery becomes somewhat complicated. In 9-mm. embryos, where the fenestra hypophyseos is still open, it runs forwards below the trabecula until in the anterior region it passes dorsally round the narrow neck of the ethmoidal cartilage to supply the olfactory organ and capsule. Later, however (12-mm. embryos), the fenestra hypophyseos closes up *below* it, so that for part of its course it runs inside the cranial cavity, entering together with the arteria carotis cerebralis and arteria ophthalmica, and leaving through a small foramen in the floor of the chondrocranium just anterior to the oculomotor foramen. Eventually, shortly before metamorphosis, with the lengthening of the branches of the internal carotid, the anterior palatine artery branches off the a. carotis cerebralis inside the cranial cavity, but can always be distinguished from branches of the latter by the fact that it crosses the optic nerve ventrally and not dorsally. Its anterior end becomes enveloped in the cartilage of the developing olfactory capsule. During metamorphosis the artery shrinks and disappears, its function

apparently being taken over by the increasingly important a. carotis cerebralis anterior.

Marshall (1909) figures an anterior and a posterior palatine artery for embryos of *Rana temporaria*, of which the posterior is a branch of the first aortic arch, but according to him it is apparently the anterior palatine artery which gives rise to the a. palatina of the adult.

Of the three end branches of the internal carotid, further mention may be made of the ophthalmic artery. The trabecula of the skull is laid down below it (9-mm. embryos), so that it enters the cranial cavity together with the a. carotis cerebralis through the carotid foramen, then turns outwards over the trabecula. Later (12-mm.) it leaves the cranial cavity through the oculomotor foramen. After metamorphosis, with the disappearance of the processus ascendens, it comes to lie completely outside the cranial cavity.

Fourth Stage.

In 7-mm. embryos the stomodaeum has broken through to the gut and the second gill slit opens direct to the exterior. Cartilage is present in the hyoid and mandibular arches and is appearing in the branchial arches and the base of the chondrocranium.

The structure of the third and fourth aortic arches is much the same as in the preceding stage, except that the loop formed by the secondary vessel has grown further back into the enlarging external gill and can now be differentiated into an afferent and an efferent part. The fourth arch has acquired an anastomosis between the afferent part of the loop and the primary vessel. In cases where a double external gill is present it is this anastomosis which grows back into it to form a vascular loop (see Pl. IV, fig. 3). The structure of these two arches, as noted by Paterson (1942), is so far almost exactly like that of young *Rana* embryos, before the external gills of the latter have acquired their arborescent outgrowths and the rupture in the primary vessel has occurred.

The course of the sixth arch is now apparent. It separates from the fifth arch and passes posteriorly and outwards along the fourth branchial arch. It then bends forwards and almost immediately backwards again to run along the thin-walled air-sac, which is the rudiment of the lung, as the pulmonary artery. It is evident thus that the ductus Botalli has already broken down. Its dorsal remains, however, can be seen joining the paired dorsal aorta immediately behind the fifth arch. By sectioning a slightly younger embryo (6·5 mm.) it was possible to obtain a stage in which the ductus Botalli is intact. Here, however, the ventral part of the arch has not yet acquired a wall but is merely a slit-like aperture in the mesenchyme. In *Xenopus*, then, the ductus Botalli persists for an extremely short period—

in fact it disappears as soon as the ventral connexion of the sixth aortic arch with the heart is established, and the arch functions thereafter as a pulmonary artery passing direct to the air-sac.

Further Development of the Aortic Arches.

In 8-mm. embryos (Pl. IV, fig. 3; Pl. VII, fig. 1) the external gills with their vascular loops reach their maximum length. At this stage all three gill slits are open to the exterior and the opercular fold has not yet closed over them. Of these the first (second embryonic, see footnote, p. 219) opens direct to the exterior, while the second and third (third and fourth embryonic) join and open through a common aperture.

In 10-mm. embryos (Pl. V, fig. 1; Pl. VII, fig. 2) the external gills are becoming covered by the growing opercular fold and are commencing to shrink. The shrinkage takes place extremely rapidly, and in 11-mm. embryos nothing remains but small pigmented knobs. The neotenic nature of *Xenopus* is clearly shown by this arrested development of the external gills and by the failure of the internal gills to appear at all.

With the disappearance of the external gills the vascular loops supplying them (the secondary vessels of the third and fourth aortic arches) become narrower, shrink, and finally vanish. The embryo is left with three continuous aortic arches (the third, fourth, and fifth) and a well-developed pulmonary artery. Of these the third aortic arch is broader and better developed than the others and appears to carry the main blood-stream from the heart to the dorsal aorta.

This preponderance of the third aortic arch over the fourth and fifth increases up to the time of metamorphosis—an unusual feature which has already been mentioned by Nikitin (1925). The function of the fourth arch is chiefly to supply blood to the elaborate filter apparatus (see p. 225), and its connexion with the paired dorsal aorta is very narrow.

The fifth aortic arch loses its connexion with the paired dorsal aorta before the tadpole acquires its maximum size (at about 44 mm., largest tadpoles measure 50–57 mm.), but the ventral portion persists until metamorphosis (see Pl. V, fig. 2).

It may be noted here that no splitting of the primary aortic arch occurs in *Xenopus* as is described by Maurer (1888) and Boas (1882) for *Rana*. After the disappearance of the secondary vessel, the primary vessel persists to form the aortic arch of the adult. Paterson (1942) states that after the disappearance of the external gills the fourth aortic arch (second adult arch) loses its connexion with the lateral dorsal aorta, and is reformed again during metamorphosis. This statement is definitely erroneous since the fourth aortic arch has been traced by the author in embryos of 10, 14, 18,

24, 31, 37, and 44 mm., and though narrow, it is unquestionably present and functional throughout larval life.

In a large tadpole of 44 mm. the median dorsal aorta extends back through the body into the tail as the caudal artery. The fore-limb, which has not yet burst through the opercular fold, is supplied by a subclavian artery which has arisen as a branch of the a. occipito-vertebralis. The latter artery appears for the first time as a minute branch of the paired dorsal aorta in 9-mm. embryos. Immediately posterior to the junction of the paired dorsal aortae arises the a. coeliaco-mesenterica which passes ventrally and breaks up to supply the gut. The a. cutanea magna appears only during metamorphosis as a branch of the pulmonary artery, so that any cutaneous respiration in the tadpole stage must take place directly through the tissues and the delicate skin.

At metamorphosis the whole branchial basket shrinks and disappears together with the filter apparatus, causing radical changes in the arterial system. The portion of the paired dorsal aorta connecting the third and fourth arches (the ductus caroticus) disappears, leaving the third aortic arch to form part of the internal carotid artery. The arteries to the filter apparatus disappear and the fifth aortic arch vanishes altogether. At the same time the fourth aortic arch broadens and takes over the main blood-stream to the aorta.

The Filter Apparatus and its Arteries.

The arteries of the filter apparatus in *Rana* have been adequately described and figured by Maurer (1888) and Boas (1882), and the salient features of the corresponding arteries in *Xenopus* have been mentioned by Nikitin (1925). The arrangement of the arteries in *Xenopus* is fundamentally the same as in *Rana*, though the system is more intensely vascularised, undoubtedly to compensate for the lack of internal gills.

The filter apparatus is not present in the earliest stages, but appears and reaches a functional condition in embryos of 10 mm., *i.e.* just at the time when the external gills are shrinking and disappearing. The arteries supplying it soon make their appearance and assume the following typical arrangement (see Pl. V, fig. 2). The third aortic arch is not concerned with the supply of the filter apparatus. The fourth aortic arch gives off a strong branch soon after leaving the heart, which passes between the second and third branchial arches on to the dorsal surface of the branchial skeleton and here divides into two. Of these, one branch runs forwards for a short while, then turns outwards to supply the first branchial arch, while the other runs along the second branchial arch. The artery of the third branchial arch arises from the sixth aortic arch at the point where the latter separates from the fifth, and passes dorsally between the third and fourth

branchial arches. The fourth branchial arch is supplied by several branches given off by the sixth aortic arch and passing dorsally between the third and fourth branchial arches. In all cases the arteries break up into capillaries beneath the epithelium of the filter apparatus.

Blood from the filter apparatus is returned to the venous system and not to the aortic arches. In spite of this fact Beddard (1894) and Dreyer (1914) both ascribed a respiratory function to the filter apparatus in addition to its obvious one of filtering food material from the outgoing water current. This theory is favoured by the author on the grounds of the intense vascularisation of the filter apparatus. It is supported by the following facts: (*a*) internal gills are absent; (*b*) the arteria cutanea magna does not appear until metamorphosis; and (*c*) the lungs, though present from an early stage, are simple, undivided sacs and do not appear capable of playing any important part in respiration. Moreover, the tadpole in normal conditions rarely comes to the surface to breathe air.

The nature of the epithelial coating of the filter apparatus is unusual. Over the surface are numerous small hillocks or projections, each bearing a number of minute, delicate, and transparent papillae, each of which is formed by a single epithelial cell (Pl. VIII, fig. 1). It is difficult to deduce the exact function of these papillae, and it can only be said that they are probably concerned either with the collection of food or with respiration.

Arterial Supply of the Muscles connected with the Branchial Skeleton.

The ventral branchial muscles in *Xenopus* consist of four subarcuales recti and a single transversus ventrali on each side (see Pl. V, fig. 1). In addition there are two hypobranchial spinal muscles with attachments to the branchial skeleton—the anterior end of the rectus cervicis is attached to the third branchial bar and the posterior end of the geniohyoideus to the first branchial bar. The arterial supply of these muscles is as follows (see Pl. V, figs. 1 and 2):—

M. geniohyoideus and m. subarcualis rectus i are supplied by branches of the a. carotis externa.

M. transversus ventralis ii and m. rectus cervicis are supplied by the ramus muscularis of a. carotis externa.

M. subarcualis rectus ii is supplied by a branch of the filter apparatus artery of the first branchial bar (itself a branch of the fourth aortic arch).

M. subarcualis rectus iii is supplied by a branch of the fourth aortic arch.

M. subarcualis rectus iv is supplied by several small branches of the filter apparatus arteries of the fourth branchial bar.

The dorsal branchial muscles, which consist of four constrictores branchiales, are supplied by a branch of the third aortic arch described below.

Accessory Branch of the Carotid Arch.

In a previous paper (Millard, 1942) mention was made of an abnormal branch of the carotid arch which occurs in approximately 42 per cent. of the adult animals. It supplies small branches to the pharynx, oesophagus, thymus gland, annulus tympanicus, and various muscles (petrohyoideus, cucullaris, depressor mandibulae, subhyoideus (or interhyoideus), masseter major and minor (or adductor mandibulae posterior); and it was assumed that it represents a persistent larval artery.

In the tadpole a branch is given off by the carotid arch just before it joins the paired dorsal aorta, which is undoubtedly this larval artery. It appears for the first time in 10-mm. embryos and divides immediately into an anterior and a posterior branch, both of which break up to supply the mm. constrictores branchiales. In later stages, in addition to these muscles, branches supply the thymus gland and the membrane roofing the gill basket.

This artery, when it persists in the adult stage, continues to supply the thymus, pharynx, m. petrohyoideus, m. cucullaris (both of which have developed from the constrictores branchiales of the larva—Edgeworth, 1935), and surrounding structures.

Experiments on the Destruction of the Larval Aortic Arches.

The impulse for this part of the work was obtained from two papers by Figge (1930 and 1934) on the effect of ligation of the pulmonary arch in the larvae of *Ambystoma tigrinum*. He found that animals treated in this manner failed to metamorphose and that the condition of the arteries resembled that of the perennibranchiate *Necturus*, *i.e.* the lungs were supplied with blood through a persistent ductus Botalli. It was thought that similar experiments on *Xenopus* might throw a further light on the development of the aortic arches.

Xenopus tadpoles are particularly suitable for this type of experiment because of their almost complete transparency—under a dissecting microscope the blood corpuscles can be observed with the greatest of ease coursing along the aortic arches.

It was found, however, that it was not practicable to ligature the arches, since owing to the extreme delicacy of the tadpoles the amount of damage involved invariably resulted in death. A better method was accordingly tried and found successful, in which the vessel concerned was destroyed with a rapid thrust from a red-hot needle.

Tadpoles were first anæsthetised with 3 per cent. chloretone (0·5 c.c. in 100 c.c. water), rapidly operated on under a dissecting microscope, and placed in running water to recover.

In this manner 30 animals were treated for each of the following groups (except group 4, where only 26 animals were used):—

(1) Control. Animals anæsthetised and allowed to recover, but not operated on in any way.
(2) Carotid arch destroyed on left side only.
(3) Carotid arch destroyed on both sides.
(4) Fourth aortic (systemic) arch destroyed on left side only.
(5) Fourth aortic arch destroyed on both sides.
(6) Pulmonary arch destroyed on left side only.
(7) Pulmonary arch destroyed on both sides.

Results.

TABLE I.—*The Mortality of Animals during* 10-*Day Intervals after Destruction of Aortic Arches. Operations Performed between the* 11*th and* 18*th December* 1940.

	Control.	1 carotid destroyed.	2 carotids destroyed.	1 systemic destroyed.	2 systemics destroyed.	1 pulmonary destroyed.	2 pulmonaries destroyed.
Not recovered from anæsthetic.	..	..	30				
11–20 Dec. 1940 .	..	28	..	4	20	13	28
21–30 Dec. 1940 .	..	2	..	1	1	16	1
31 Dec.–9 Jan. 1941	1	..	..	6	3		
10–19 Jan. 1941 .	4	..	..	15			
20–29 Jan. 1941 .	4	..	..	1	..	1	1
30 Jan.–8 Feb. 1941	11						
9–18 Feb. 1941 .	8						
Survivors on 19 Feb.	2	..	..	3	2		
Total .	30	30	30	30	26	30	30

1. *Control.*—All animals recovered perfectly from the anæsthetic, but a certain amount of difficulty was experienced in rearing them in the laboratory, due chiefly to the necessity for a continual supply of vast quantities of small protozoa and entomostraca as food. The animals were treated between the 13th and 18th December 1940, and from the 7th January 1941 gradually started dying off. Some of those which died were tadpoles, others had completed their metamorphosis. It seems, then, that a certain mortality must be expected in any case. The most susceptible

period in the life-history appears to be immediately after metamorphosis, *i.e.* the time when the animal stops feeding passively by means of the filter apparatus and has to capture its own food. This stage, however, is quite sufficiently advanced for the present purpose, since the aortic arches have already assumed the adult form. The young frogs were fixed immediately after death and the fate of the aortic arches determined by sectioning.

2. *Left Carotid Arch Destroyed.*—These animals, though they recovered from the anæsthetic, did not survive more than a few days. Of the 30 animals operated on between the 11th and 18th December, all were dead by the 23rd.

3. *Both Carotid Arches Destroyed.*—None of these animals recovered from the anæsthetic.

4. *Left Systemic Arch Destroyed.*—In this group all the animals recovered successfully from the anæsthetic and appeared none the worse for the operation. The mortality was not much greater than the control group, although more animals died during the early part of the experiment. Nine successfully completed metamorphosis, but died soon after. Six of these were sectioned to determine the condition of the arteries.

It was found that in all these animals the condition of the arteries on the left side resembled that figured in Pl. VIII, fig. 2, A, with slight variations, the right side being normal. The remains of the original systemic arch was visible as a stump leaving the truncus arteriosus and sometimes even containing blood corpuscles, but ending blindly soon after. In one case the stump of the systemic arch ended blindly in the wall of the truncus. In all cases the left carotid arch was connected to the paired dorsal aorta by the persistent ductus caroticus. The latter in one animal had closed and ceased to function, so that the left subclavian artery received its blood from the right side of the body. In all the others the left subclavian was supplied *via* the carotid arch and persistent ductus caroticus. The left paired dorsal aorta from this point on was slightly narrower than the right, and in three cases was extremely narrow.

5. *Both Systemic Arches Destroyed.*—These animals recovered satisfactorily from the anæsthetic, but all except two were dead by the 4th January. These two completed metamorphosis and grew into lusty young frogs. On the 19th June they were killed. Both were large enough for macroscopic dissection and one for injection.

In both animals the systemic arch of the right side had regenerated, although in one there was the remains of a closed ductus caroticus connecting it with the carotid arch. On the left side the arteries were similar to those of the previous group—the systemic arch was missing, and the carotid arch communicated with the paired dorsal aorta by means of the ductus caroticus.

It appears thus that the animals are not able to survive the destruction

of both systemic arches, but in the event of the regeneration of one, they are outwardly little effected by the operation.

6. *Left Pulmo-cutaneous Arch Destroyed.*—This operation and that of the next group were more difficult than the preceding ones, since the pulmonary arch lies close against the peritoneum of the abdominal cavity. In some cases the peritoneum was damaged and the animals did not recover from the anæsthetic. These specimens were disregarded in Table I.

Of the 30 successfully treated animals of this group, all except one were dead by the 27th December. The surviving animal completed metamorphosis and died on the 22nd January.

On sectioning it was found that the original pulmo-cutaneous arch ended blindly soon after leaving the heart. The distal portion, however, had acquired a secondary connexion with the subclavian artery on that side (see Pl. VIII, fig. 2, B). This, obviously, is not due to the persistence of the ductus Botalli, since the latter vessel, as has been mentioned on p. 223, disappears very early in larval life, but to the establishment of an entirely new connexion. Those tadpoles which were not able to establish such a connexion died almost immediately.

7. *Both Pulmo-cutaneous Arches Destroyed.*—Of the 30 animals which recovered successfully from the anæsthetic all except one were dead by the 23rd December. The remaining animal completed metamorphosis and died on the 27th January. Sections revealed that it had regenerated both pulmo-cutaneous arches and was to all appearances perfectly normal.

It appears thus that the animals cannot exist without at least one normal pulmo-cutaneous arch.

Discussion of Results.

The fact that the tadpoles cannot survive the destruction of one carotid (3rd aortic) arch and do not even recover from the anæsthetic when both are destroyed, emphasises the importance of this arch during larval life, and supports the statement made (p. 224) that the carotid arches carry the main supply of blood to the dorsal aorta. Neither the 4th nor the 5th arches are strong enough to take over this function.

On the other hand, the animals are able to survive without any apparent inconvenience the loss of one systemic (4th aortic) arch, though not both. The condition of the arteries in these frogs is always the same—the ductus caroticus persists in the adult stage connecting the carotid arch with the paired dorsal aorta. Only in one animal had the ductus caroticus closed and ceased to function.

This condition is reminiscent of an abnormality described in a previous paper (Millard, 1942, p. 14), where the systemic arch was absent on the left side and the subclavian and oesophageal arteries were supplied by the

carotid arch through what appeared to be a persistent ductus caroticus. The region of the paired dorsal aorta between the origin of the subclavian artery and the junction of the paired dorsal aortae, however, had disappeared altogether in this specimen.

Animals without a pulmo-cutaneous arch are unable to survive except in the unlikely event of regeneration of the destroyed arch or the establishment of a new connexion. It may be mentioned here that the tadpoles treated were all well-grown, measuring between 3·5 and 5 cm. approximately, and none had really commenced metamorphosis. The results appear to show that pulmonary respiration is essential during the latter part of larval life. This does not interfere with the conclusion reached previously that the filter apparatus also has a respiratory function, for the filter apparatus is supplied by the fourth and sixth aortic arches, and it has already been shown that tadpoles die when bereft of both systemic (4th aortic) arches.

Summary.

Five complete aortic arches are laid down in *Xenopus* embryos and a vestige of a sixth.

The first aortic (mandibular) arch is the first to appear, in embryos of 4 mm. In 6-mm. embryos it has started to degenerate—the proximal ventral end remains attached to the third aortic arch as part of the external carotid artery, the middle part disappears, and the dorsal end forms part of the posterior palatine artery of the embryo (*i.e.* the a. palatina of the adult). There is also an anterior palatine artery in the embryo which vanishes at metamorphosis.

The third and fourth aortic arches and the vestige of the second appear next in 5-mm. embryos. The last is a blind stump joining the paired dorsal aorta and disappears almost immediately. The third and fourth aortic arches are laid down as irregular spaces in the mesenchyme, and each divides into an anterior and posterior vessel which join again midway round the gut. These are the primary and secondary vessels of Maurer and they appear simultaneously. The secondary vessels shift more posteriorly and form vascular loops extending into the external gills, which are borne on the first and second branchial arches. They reach their maximum size in 8-mm. embryos, then shrink and disappear. The primary vessels form the aortic arches of the adult and are not interrupted at any stage.

The fifth aortic arch is complete in 6-mm. embryos and never possesses a secondary vessel. It loses its connexion with the paired dorsal aorta late in larval life (44-mm. embryos) and disappears entirely at metamorphosis.

The sixth aortic arch is complete only for a very short interval (6·5-mm.

embryos). Almost immediately the pulmonary artery is laid down and the ductus Botalli disappears.

In larval life the third aortic arch is better developed than any of the others and carries the main blood-stream to the paired dorsal aorta. The filter apparatus is considered to have a respiratory function and is supplied by the fourth and sixth aortic arches. The arrangement of these vessels is similar to that of *Rana*.

The abnormal accessory branch of the carotid arch occurring in a certain percentage of adults was found to be a persistent larval artery responsible for supplying chiefly the constrictores branchiales muscles.

Experiments on the destruction of the larval aortic arches show:

(*a*) That tadpoles with one or both carotid (third aortic) arches destroyed cannot survive.

(*b*) That tadpoles can survive the destruction of one systemic (fourth aortic) arch, in which case the carotid arch retains its communication with the paired dorsal aorta through the ductus caroticus.

(*c*) Tadpoles cannot survive without a pulmo-cutaneous (sixth aortic) arch unless a secondary connexion is established.

ACKNOWLEDGMENTS.

The author wishes to thank Professor C. G. S. de Villiers of the University of Stellenbosch for his advice and criticism, and also Dr. H. Sandon of the University of Cape Town for reading the manuscript.

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DESCRIPTION OF PLATES.

Plate IV.

Fig. 1.—Reconstruction of aortic arches of 5-mm. embryo, ventral view. The first, third, and fourth arches are complete, and the latter two possess primary and secondary vessels. × 109·5.

Fig. 2.—Reconstruction of aortic arches of 6-mm. embryo, ventral view. The third, fourth, and fifth arches are complete, the first arch is degenerating at *x*, and there are stumps of the second and sixth arches. × 109·5.

Fig. 3.—Reconstruction of aortic arches of 8-mm. embryo, ventral view. The secondary vessels of the third and fourth arches form loops projecting backwards into the external gills. The right side (left side of diagram) is unusual in that there are two external gills on the first branchial arch. The second of these is supplied by an extra loop formed by the anastomosis between the third aortic arch and its secondary vessel. × 109·5.

Plate V.

Fig. 1.—Reconstruction of aortic arches, branchial skeleton and associated muscles of 10-mm. embryo, ventral view. The vessels supplying the external gills have started to

shrink and the third aortic arch has become broader than the others. The arteries to the filter apparatus have been omitted. × 55·0.

Fig. 2.—Reconstruction of aortic arches of embryo with four legs before commencement of metamorphosis, showing the arterial supply of the filter apparatus (speckled). Ventral view. Note relative sizes of aortic arches. The fifth arch has started to degenerate. × 12·2.

PLATE VI.

A series of horizontal sections through a 6-mm. embryo, showing the rudiments of the mandibular, hyoid, and branchial arches (*mand. a., hy. a., branch. i–iv*), and of the gill clefts (*sp., g.c. i–iv*), none of which are as yet open to the exterior. Fig. 1 is the most ventral and fig. 4 the most dorsal. × 75·5.

PLATE VII.

Fig. 1.—Transverse section through 8-mm. embryo, through the region *XX* of Pl. IV, fig. 3. Stage with external gills. × 90·3.

Fig. 2.—Transverse section through 10-mm. embryo, through the region *YY* of Pl. V, fig. 1. Operculum (*op.*) closing over external gills (*e.g.*) and filter apparatus developing. × 60·6.

PLATE VIII.

Fig. 1.—Portion of the filter apparatus in detail showing the respiratory papillae (*pap.*). × 318·2.

Fig. 2.—Diagrams of the arterial systems of two frogs, in which aortic arches were destroyed during the tadpole stage. Ventral view. In A the fourth (systemic) arch of the tadpole was destroyed on the left side and the ductus caroticus persists. In B the sixth (pulmo-cutaneous) arch was destroyed on the left side and pulmonary and cutaneous arteries have an abnormal connexion with the subclavian.

ABBREVIATIONS.

A.c., auditory capsule; anast., anastomosis; aud., auditory vesicle; bas., basihyal; bl. v., blood vessel; branch. i–iv, branchial bars i–iv (rudiments in Pl. VI); car. ext., arteria carotis externa; car. int., arteria carotis interna; cart., cartilage; cer., ceratohyal; conn., connective tissue; cut. mag., arteria cutanea magna; d. car., ductus caroticus; e.a., external aperture of gill chamber; e.g., external gill; epith., epithelium; f.a. branch. i–iv, arteries to filter apparatus of branchial bars i–iv; g.c. i–iv, gill clefts i–iv; g.gl., ganglion glossopharyngeus; g.pro., ganglion pro-oticum; h., heart; hy.a., hyoid arch rudiment; i.l.c., inferior labial cartilage; mand.a., mandibular arch rudiment; Meck., Meckel's cartilage; m.con. br., musculus constrictor branchialis; m.gen., musculus genio-hyoideus; m.interhy., musculus interhyoideus; m. intermand., musculus intermandibularis; m.orb.-hy., musculus orbito-hyoideus; m.quad.-hy.-ang., musculus quadrato-hyo-angularis; m.rect. cerv., musculus rectus cervicis; m.sub.rect. i.–iv, musculi subarcuales recti i–iv; m.tr.vent ii, musculus transversus ventralis ii; occ.-vert., arteria occipito-vertebralis; oes., arteria oesophagea; olf., olfactory organ; op., operculum; pal., arteria palatina; pap., respiratory papillae of filter apparatus; pch., parachordal; p.d.a., paired dorsal aorta; peric., pericardium; ph., pharynx; pr. 3, primary vessel of the 3rd aortic arch; pr. 4, primary vessel of the 4th aortic arch; pulm., arteria pulmonalis; pulm.-cut., arteria pulmo-cutanea; r.musc., arteria carotis externa, ramus muscularis; sec. 3, secondary vessel of the 3rd aortic arch; sec. 4, secondary vessel of the 4th aortic arch; sp., spiracle; subcl., arteria subclavia; tr., truncus arteriosus; v., vein; v.cap.lat., vena capitis lateralis; v. jug.ext., vena jugularis externa; x, degenerating part of 1st arch; 1–6, aortic arches 1–6; II, VIII, IX, cranial nerves II, VIII, and IX.

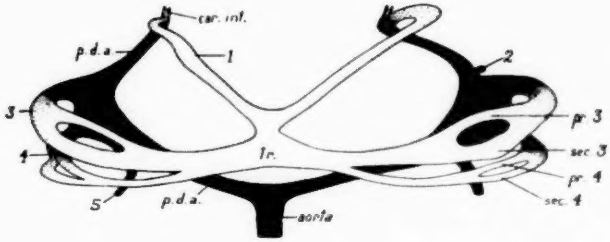
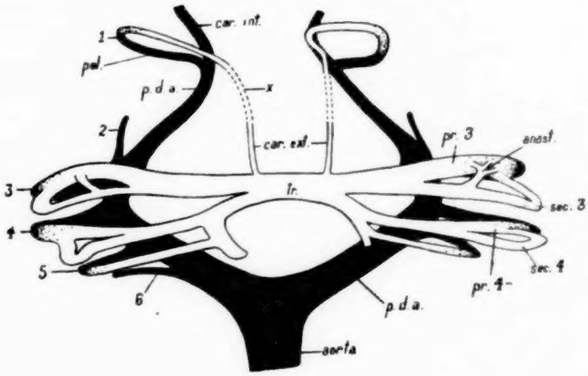


Fig. 1.



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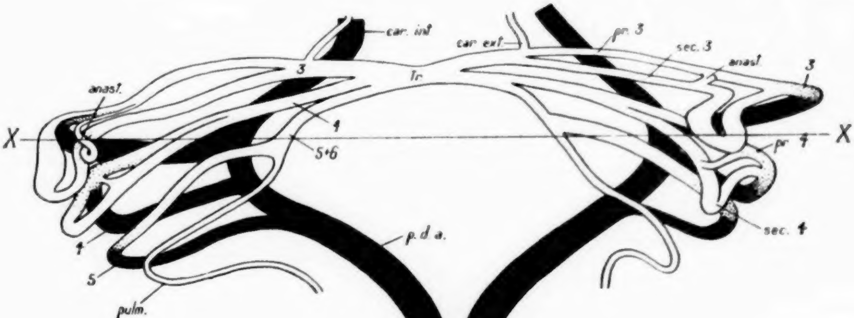
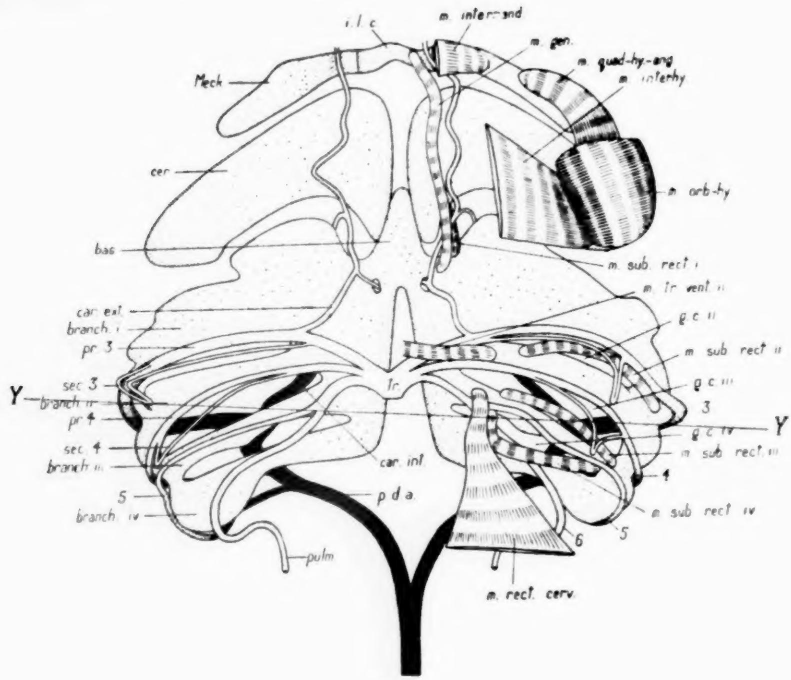


Fig. 3.


i. l. c.
m. intermand.
m. gen.
m. quad-hy-ang
m. interhy
Meck
cer
m. orb-hy
bas
m. sub. rect. i
m. tr. vent. ii
car. ext.
branch. i
g. c. ii
pr. 3
m. sub. rect. ii
sec. 3
g. c. iii
Y
branch. ii
3
pr. 4
tr.
g. c. iv
Y
sec. 4
m. sub. rect. iii
branch. iii
car. int.
4
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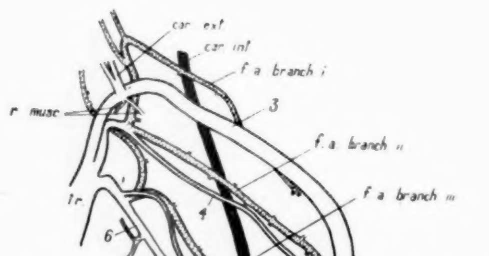
branch. iv
5
6
pulm
m. rect. cerv.

Fig. 1.


car. ext.
car. int.
f. a. branch. i
r. musc.
3
f. a. branch. ii
f. a. branch. iii
tr.
4
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f. a. branch. iv
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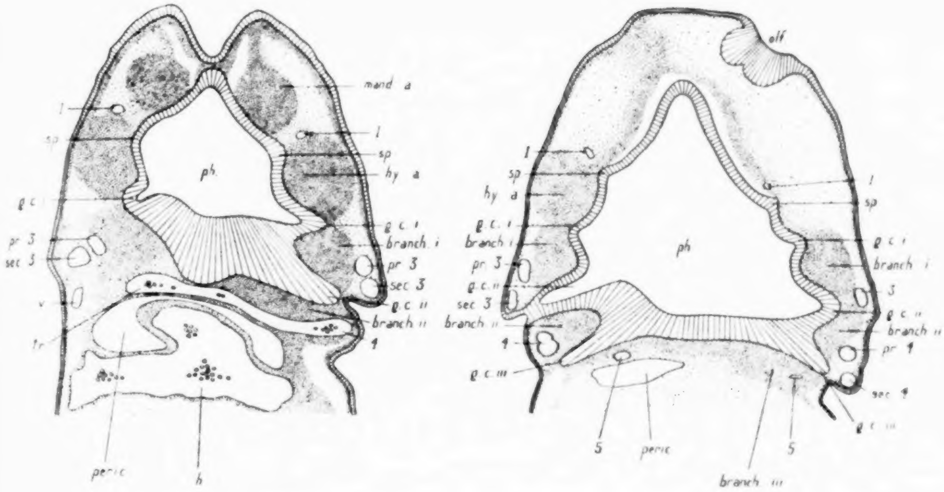
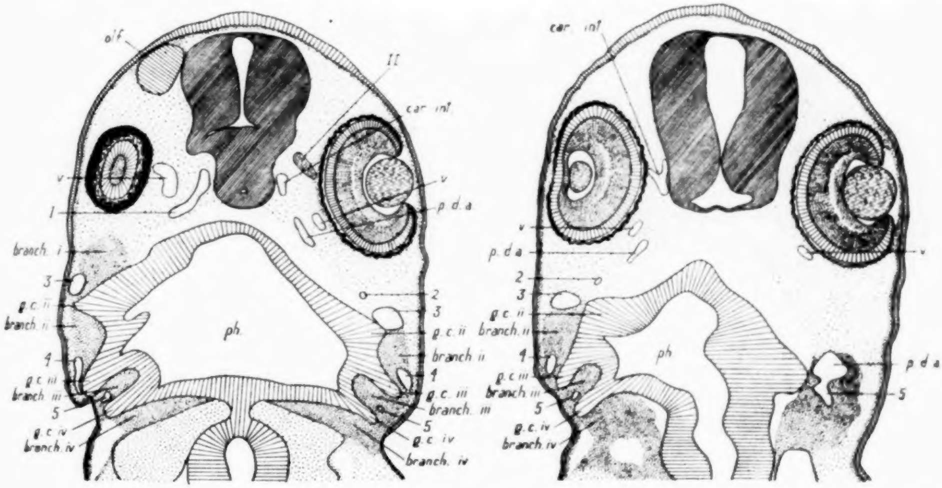
Fig. 2.



1 2

FIG. 1.



3 4

FIG. 2.

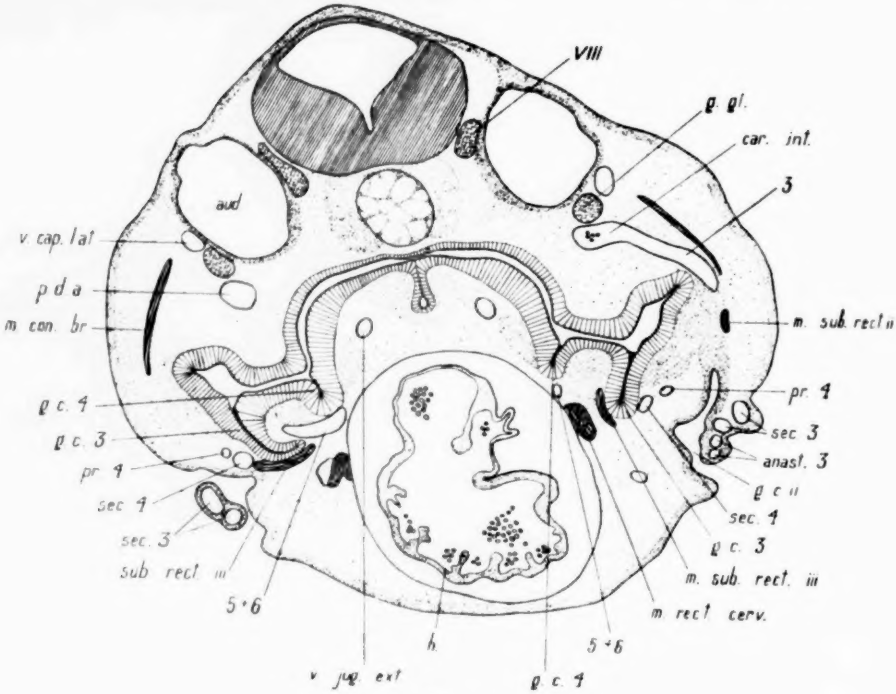


Fig. 1.

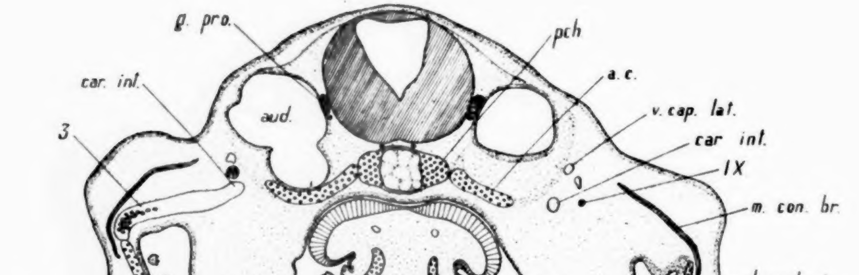
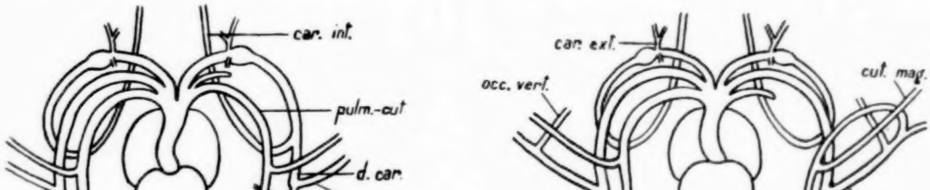


Fig. 2.

Naomi Millard. Neill & Co., Ltd.


pap.
bl. v.
bl. v.
conn.
cart.
epith.
bl. v.

FIG. 1.


car. int.
pulm.-cut
d. car.
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oes.
A
car. ext.
occ. vert.
cut. mag.
subcl.
pulm.
B

FIG. 2.

THE CYTOLOGICAL BASIS OF VARIATION IN VARIETIES OF *NICOTIANA TABACUM*.

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Tobacco Research Station, Trelawney, S. Rhodesia.

(Communicated by G. Arnold.)

(With one Text-figure.)

(Read May 19, 1943.)

Introduction.

The investigations into the cytological behaviour of tobacco varieties described in this paper were undertaken in conjunction with a programme of breeding. It was noticed that in spite of continued selection over a number of years for morphological uniformity, aberrant types appeared from time to time. The changes consisted of striking differences in leaf shape, leaf number, general habit of the plant, colour and texture of leaves, etc. The occurrence of such types in what frequently appeared to be a true breeding variety led to the conclusion that much of the observed variability was due to cytological disturbances, rather than to the mutation or segregation of genes present in the heterozygous condition. The aim of the investigation was, therefore, to determine the causes of variability in tobacco and the probable effects from a purely practical point of view. Particular attention was paid to abnormalities at meiosis which might bring about morphological changes.

Material and Methods.

Varieties differing as widely as possible in morphological characters and in locality of origin were selected for the investigation. Crosses between varieties were also examined to determine to what extent chromosome differentiation had taken place.

The following were examined:—

Jamaica Wrapper.	Jamaica Wrapper × Ambalema.
White Stem Orinoco.	White Stem Orinoco × Ambalema.
Ambalema.	White Stem Orinoco × Vumba.
Vumba.	Ambalema × Vumba.
Meadows Giant.	

Jamaica Wrapper and White Stem Orinoco were imported originally from the United States of America, and have been grown commercially in this country for a number of years. Ambalema and Vumba differ widely from each other and from the commercial varieties. Ambalema was obtained from Cuba, and at the time of making the preparations had been grown in Rhodesia for one year only. Vumba was obtained from the eastern border of Southern Rhodesia, where it is alleged to have been grown by the natives for a very long time. Meadows Giant is a mutant type from White Stem Orinoco.

Material was taken from the experimental plots in the height of the growing season. All observations were made on smear preparations fixed in 2 BE and stained with Gentian Violet. Permanent aceto-carmine preparations gave good fixation, but staining was not deep enough for detailed observations.

Secondary Association.

In all the varieties and strains examined, the chromosome number was found to be $2n = 48$. At meiosis twenty-four bivalents were formed, except in a small number of cells where some evidence of the occurrence of multivalents was obtained. In polar views of metaphase I, the bivalents showed a definite secondary association, the degree of which is given in the Table in an analysis of 44 metaphase plates. The plates were taken from all the varieties examined as no evidence of differences in the degree of association was found between varieties.

Table.

Degree of Secondary Association in Tobacco Varieties.

No. of Bivalents in Group.	III.	4	4	4	3	3	3	3	3	2	2	2	2	2	1	1	1	1	1
	II.	6	5	4	7	6	5	4	3	8	7	6	5	3	9	8	7	6	5
	I.	..	2	4	1	3	5	7	9	2	4	6	8	12	3	5	7	9	11
No. of cells		1	4	3	3	5	2	2	1	1	5	1	2	2	5	4	1	1	1

The analysis of metaphase plates for secondary association of chromosomes is liable to considerable error, and may vary with the individual observer. In the above Table cells in which the association was indeterminate were ignored, and only those in which counts of associations could be made with some accuracy included. The maximum association observed was four groups of three bivalents and six groups of two bivalents, giving in all ten chromosome groups. This grouping was observed in one cell only, all other cells showing a lesser degree of association, but in such a manner as to indicate that where the maximum association occurred, ten chromo-

some groups would be formed. Thus, in the Table it will be noticed that where the number of secondary associations of three bivalents is three, two, and one, the maximum number of associations of two bivalents is seven, eight, and nine respectively. More than four groups of three bivalents were not observed. This grouping of bivalents might be taken as evidence of an original basic number of ten. In view, however, of the evidence of structural hybridity discussed below, it is simpler to assume for the time being that the secondary association is merely due to reduplication of segments of chromosomes having taken place within the haploid complement.

Structural Hybridity.

Tobacco is unfavourable material for a detailed study of chromosome behaviour, owing to the large number of chromosomes and a tendency for the metaphase plates to be crowded at meiosis. Observations were confined, therefore, principally to polar views and to first and second anaphase. The interpretation of the observed abnormalities as evidence of structural hybridity is based on analogy with other organisms which offer more favourable material for detailed chromosome studies (Richardson, 1936; Darlington, 1936; Upcott, 1937). In all the varieties and hybrids examined the chromosome behaviour was very similar, and the one description of meiosis will serve for all.

At metaphase I, the presence of multivalent associations was suspected in a number of cells, but in no case could the presence of a multivalent be established definitely by direct observation. Indirect evidence as follows was, however, obtained which led to the conclusion that multivalents do occur in a small proportion of cells:—

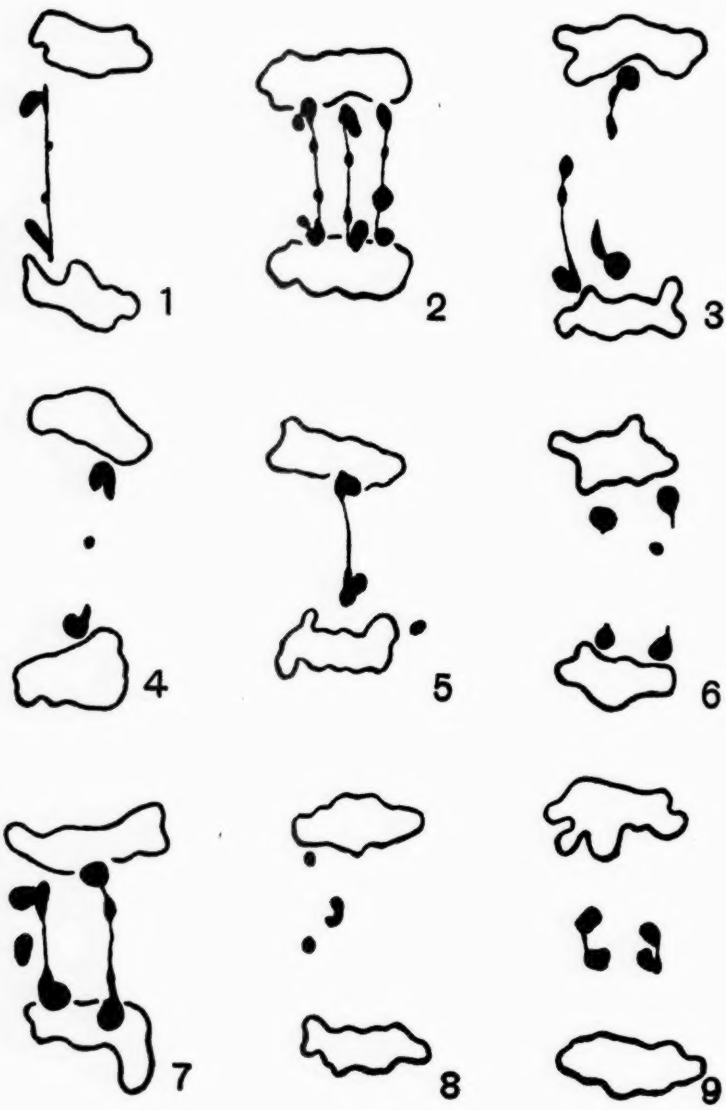
(1) Bodies were observed in metaphase plates which, by their shape and orientation, did not appear to be bivalents.

(2) Occasionally, one or two univalent chromosomes were observed lying off the plate at metaphase I.

(3) Univalents were observed dividing at anaphase I without any evidence of a chromatin bridge having been present (figs. 8 and 9).

The presence of two univalents might be due to the suppression of crossing over due to structural hybridity, but the presence of a single univalent points rather to trivalent formation. It is probable, therefore, that a small amount of allosyndetic pairing takes place in *N. Tabacum.*

Irregularities of a different type were observed at the later stages of meiosis. At anaphase I, in a small proportion of cells, chromosome separation was accompanied by strands or bridges of chromatin between the separating chromosomes. Sometimes these bridges were accompanied by a small fragment (figs. 4–7), but in the majority no fragment was observed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9

(figs. 1–3). The similarity of these bridges to those occurring in other organisms in which chromosome behaviour can be studied in greater detail, leaves no doubt that they are due to crossing-over in relatively inverted segments of chromosomes. The fact that the bridges frequently occurred without a visible fragment, presents a difficulty since, theoretically, where a dicentric bridge is formed, an acentric fragment should occur. Darlington and Gairdner, 1937, and Darlington, 1937, reported similar cases in *Campanula persicifolia* and *Tradescantia* where fragments are not always visible, and concluded that they may have become lost in the general body of the chromosomes or simply be too small to be seen owing to the inversion lying very close to the end of the chromosome. The absence of fragments in tobacco varieties is probably due to similar circumstances. In fig. 5, for example, the fragment has already moved away from the bridge and might easily be overlooked. The peculiar shapes of some of the bridges (figs. 1–3) is probably due to stretching of the centromere under tension.

At anaphase I the persistence of the bridges was variable, but normally all broke before telophase. Some broke at an early stage due to a short proximal segment giving rise to a short bridge (figs. 4 and 6). Where the proximal segment was longer, the bridge persisted until late anaphase, frequently becoming drawn out into a scarcely visible thread. In many cases the breakage of bridges was unequal, a larger amount of chromatin material passing to one daughter nucleus than to the other (fig. 3).

An attempt was made to make a quantitative estimate of inversion hybridity in tobacco, but the early breakage of some of the bridges rendered such a study impossible. Striking differences were observed, however, in the frequency of bridges occurring in sister plants. In particular, in one plant of White Stem Orinoco the occurrence of a single bridge was a rarity (fig. 1), while in the sister plant up to three bridges were observed in a single cell (figs. 2 and 3).

Bridges at second anaphase caused by the formation of a proximal chiasma disparate to the chiasma in the inversion, occurred in a small

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Figs. 1–3.—Anaphase I in sister plants of White Stem Orinoco showing bridges with no visible fragments.

Fig. 1. From plant with very low frequency of bridges.

Figs. 2 and 3. From plant in which bridges were numerous.

Figs. 3–7.—Bridges at anaphase I with visible fragments.

Fig. 4. White Stem Orinoco.

Fig. 5. Jamaica Wrapper.

Figs. 6 and 7. Vumba.

Figs. 8 and 9.—Univalent chromosomes dividing at anaphase I.

Fig. 8. Vumba × White Stem Orinoco.

Fig. 9. White Stem Orinoco.

proportion of cells, but were rarer than the first division bridges. In *Tulipa* (Upcott, 1937) first and second division bridges occur in about equal numbers, while in *Chorthippus* (Darlington, 1936) second division bridges occur less frequently. It would appear that comparate chiasmata are more common in *Chorthippus* and tobacco, whereas disparate chiasma occur more frequently in *Tulipa*.

In some of the varieties examined, more particularly in Ambalema, small fragments were observed at telophase and second anaphase. These fragments may be due to bridges formed at the first or second division and the fragment not becoming included in the daughter nuclei.

Discussion.

The mechanism by which dicentric bridges and acentric fragments are formed has been studied in many organisms suitable for detailed chromosome observations. In tobacco the causes and manner in which bridges arise have to be inferred and, from the point of view of breeding, the probable genetical results of structural hybridity are of greater importance than its effect on chromosome behaviour.

In diploids the formation of bridges should result in a considerable degree of sterility, since breakage of bridges and loss of fragments will lead to deficiency in respect of parts of chromosomes in a proportion of cells. In polyploids, the loss of small portions of chromosomes is not so serious since the presence of duplicated genes helps to protect them from lethal deficiencies. Cytological evidence has shown that *Nicotiana Tabacum* is an allotetraploid, and the evidence of secondary association points to the possibility of an even lower original basic number than the present X = 12. It must be assumed, therefore, that there are many duplicated genes in tobacco varieties, an assumption which is borne out by genetical and breeding experiments. With such a replication of genes, the loss or gain of small portions of chromatin material such as has been shown to occur will have little effect on fertility, although it may have a marked effect on genetical characters by altering genic balance. Darlington (1937) pointed out that long inversions, while not greatly reducing crossing-over in inverted segments, reduce fertility in the F_1 and produce a genetic isolation of individuals. Short inversions, on the other hand, have little effect on fertility, but they suppress crossing-over in the inverted segments, thus holding together groups of genes. This suppression of crossing-over produces what Darlington terms "segmental endogamy," and has the result that genes tend to be inherited in blocks rather than as individuals. Mutations arising in the regions where crossing-over is suppressed would be free from the effects of selection as individual genes since selection will only act on the gene block

as a whole. Unless, therefore, the mutations are particularly advantageous or disadvantageous, a considerable degree of heterozygosity may be built up and preserved by a combination of mutation and suppression of crossing-over. Recombination will only take place when a chiasma is formed in the inverted segment. In the case of short inversions, for every inversion which shows up cytologically owing to crossing-over, there will be numerous inversions in which crossing-over is suppressed.

The major causes of variation are, however, more probably due to structural changes in the chromosomes. As has been pointed out above, though functionally a diploid, *N. Tabacum* has nevertheless the protection of duplicated genes which will render viable the less extreme chromosome aberrations such as the addition or loss of small portions of chromosome material. It is to this type of change and to occasional allosyndetic pairing that the majority of the "mutant" types constantly appearing must be ascribed, particularly as the effect of gene mutation will be less marked in a tetraploid, owing to four sets of chromosomes concealing the individual gene.

Kostoff and Sarana (1939) in *N. Tabacum* var. *macrophylla* have, by treatment with extreme temperatures, produced chromsoome aberrations of a similar type to those described above. The chromosome changes produced were more extreme, but the genetical results are of the greatest interest since they show the types of change which must be continually occurring to a lesser degree in cultivated tobacco. Heritable variations occurred in many of the progeny, the characters involved being morphological, physiological, and biochemical. The morphological characters involved colour as well as shapes and quantities, variations occurring in leaf number, shape, colour, angle of apex, etc., while the physiological characters included changes in vegetative period and alkaloid content. These changes are very similar to those occurring in cultivated varieties of tobacco. From the point of view of practical breeding and commercial suitability, there is no need to emphasize their importance. The fact that Kostoff's variants were produced by the effect of high temperature, suggests the possibility that under Rhodesian conditions, where solar radiation is intense, chromosome aberrations are constantly being produced. It would be of interest to know whether similar aberrations occur in the same varieties grown under more temperate conditions.

The more drastic types of morphological change are easily distinguished, but further changes not so obvious and easily confused with environmental fluctuations may occur. Many of the characters which are of commercial value in tobacco are undoubtedly polygenic, *i.e.* their inheritance is controlled by a large number of genes each having an approximately equal effect. It is characteristic of characters controlled by polygenic inheritance

that they are markedly influenced by environment. Mather (1941), working on *Drosophila*, concludes that polygenes tend to form balanced combinations, and that variation stored by such combinations is subject to two balancing processes: (*a*) an internal one in homozygotes and (*b*) the relational balancing against other combinations. Where inbreeding is common, the opportunity for relational balancing will be rare, and selection may be expected to act mainly upon the internal constitution of the combinations. The stored variability then lies in its potential heterozygosity. Mather (1942) in a further paper draws the following conclusions:—

(*a*) Balancing of polygenic combinations may occur in any chromosome.
(*b*) A large change can occur under the action of selection as a result of unbalancing genes in a small segment of a chromosome.

In tobacco, as a result of primary or secondary chromosome rearrangement brought about by structural hybridity, unbalancing of polygenic combinations will probably occur, releasing variability. Under wild conditions many of these changes would be unfavourable and tend to disappear; but under cultural conditions, phenotypical or physiological variability brought about by this unbalancing of polygenes may produce undesirable (or desirable) combinations in a variety.

From a practical point of view, the plant breeder is faced with the following facts:—

(1) It is almost impossible to produce (in Rhodesia, at least) a pure breeding variety. Heritable, morphological, or physiological changes are continually arising directly or indirectly, due to structural hybridity.
(2) Many of the characteristics important from a commercial point of view are those most easily influenced by environmental conditions.

Under these circumstances, even when varieties or strains have reached a high degree of commercial suitability, selection must be continued in order to prevent undesirable types from becoming incorporated in the variety. Where variation is of a gross nature, undesirable variants are readily eliminated by selection; but where variation is of a more subtle nature, hereditary variation and environmental fluctuation may readily be confused. It is important, therefore, that in any technique of tobacco breeding, methods which eliminate environmental fluctuation should be used as far as possible.

Summary.

The cytological behaviour at meiosis of five varieties of tobacco and hybrids between these varieties is described.

Considerable evidence of inversion pairing was obtained in all the types

examined, including commercial varieties. The probable genetical results of chromosome duplications or deletions brought about by crossing-over in relatively inverted segments are discussed. From the point of view of practical tobacco breeding the difficulty in obtaining a pure breeding strain, and the necessity for continuous selection even when a variety has reached commercial suitability, are discussed.

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NEW AND HITHERTO IMPERFECTLY KNOWN SPECIES OF AFRICAN RESTIONACEAE.

By N. S. Pillans.

(Communicated by L. Bolus.)

(Read September 8, 1943.)

This paper contains descriptions of 25 new species and 3 hitherto imperfectly known species founded on material which has been worked in the Bolus Herbarium, University of Cape Town, since the publication of a similar paper in vol. xxix of these *Transactions*.

Restio *Linn.*

R. aspericaulis, sp. nov.; culmis ramosissimis gracilibus compressissimis, marginibus scabridis; vaginis arte convolutis acutis mucronatis; spiculis masculis 1–3 in spicatam cymam, cuneatis 1–2-floris; bracteis lanceolatis acutis mucronatis membranaceis; perianthio oblongo; segmentis lineari-lanceolatis acutissimis membranaceis glabris; spiculis femineis solitariis late cuneatis compressis 1-floris; bracteis 2 lanceolatis acutis cartilagineis, marginibus membranaceis; perianthio stipitato oblongo; segmentis lanceolatis acutis membranaceis; ovario uniloculato; stylistribus liberis.

Stems 20–40 cm. high, much branched, slender, very compressed, scabrid on the edges, wrinkled elsewhere. Sheaths closely convolute, lanceolate, acute, compressed laterally, coriaceous, scabrid on the dorsal edge, 1–2 cm. long with the stout mucro. Male spikelets 1 or 2 in a spicate cyme, 5–6 mm. long, cuneate, 1- or 2-flowered. Spathe sheath-like, slightly overtopping the spikelet. Bracts 2, 4 mm. long, lanceolate, acute, mucronate, membranous except for the scabrid midrib. Perianth stipitate, 3 mm. long, oblong: segments linear-lanceolate, very acute, membranous, glabrous; the inner much shorter than the outer. Female spikelets solitary on short branchlets, 6–9 mm. long, widely cuneate, compressed, 1-flowered. Spathe sheath-like, exceeding the spikelet. Bracts 2, one fertile, the other subtending a rudimentary flower-bud; fertile bract 6–9 mm. long with the stout mucro, lanceolate, acute, cartilaginous, membranous at the margins. Perianth stipitate, 4–5 mm. long, oblong, somewhat compressed: segments lanceolate, acute, membranous; the outer much exceeding the

inner. Ovary obliquely rotund, 1-chambered. Styles 3, adjacent, stout at base. Seeds rotund, with transverse wavy ridges, reddish.

South Africa: Cape Province.—Uniondale Div.: near Joubertina, Zitzikama mountains, very local on lower damp slopes, Nov. 24, 1941, *Esterhuysen* 6879 ♂ and ♀ (type, in Bolus Herbarium). Humansdorp Div.: Witte Els Bosch Peak, south-west ridge, alt. 3500 feet, Nov. 6, 1941, *Esterhuysen* 6781 ♀.

This species is related to *R. depauperatus* Kunth, from which it is easily distinguished by its much stouter and more compressed stems with rough edges.

R. aureolus, sp. nov.; culmis parce ramosis gracilibus teretibus; vaginis obtusissimis mucronatis coriaceis; spiculis femineis 1–3 in spicatam cymam, ellipticis acutis 1-floris; bracteis ovatis acutis mucronatis coriaceis, marginibus superioribus membranaceis; perianthio ovato-lanceolato; segmentis lanceolatis acutis cartilagineis, lateralibus villoso-carinatis; ovario biloculari; stylis tribus liberis.

Stems 15–20 cm. high, crowded, moderately branched, slender, terete, almost smooth, golden yellow. Sheaths at the middle of the stems about 6 mm. long, closely convolute, rounded at the upper margin, stoutly mucronate, coriaceous, red-brown, yellow-speckled, with a narrow deciduous pale-membranous upper margin. Female spikelets 1–3 in a spicate cyme, about 8 mm. long, elliptic, acute at both ends, becoming narrowly obovate, 1-flowered. Spathe sheath-like. Bracts closely imbricate, about 6 mm. long, ovate, acute, mucronate, coriaceous, red-brown, pale-membranous at the upper margin. Perianth 5·5–6 mm. long, ovate-lanceolate: outer segments lanceolate, acute, cartilaginous; the outer lateral navicular, villous carinate; the anterior glabrous: inner segments slightly shorter, ovate-lanceolate, acute, cartilaginous. Ovary rotund, 2-chambered. Styles 3, adjacent. Seeds oblong, angular, scabrid.

South Africa: Cape Province.—Worcester Div.: Hex River mountains, Buffels Hoek area, alt. 6000 feet, Dec. 26, 1942, *Esterhuysen* 8415 ♀ (type, in Bolus Herbarium).

The affinity is with *R. perplexus* Kunth and *R. patens* Mast., from which it differs by its dwarf habit, almost smooth stems and amply villous carina of the outer lateral perianth segments.

R. degenerans, sp. nov.; culmis parce ramosis gracilibus teretibus; vaginis obtusis mucronatis, marginibus superioribus membranaceis; spiculis masculis solitariis cuneatis 1-floris; bracteis oblongo-lanceolatis obtusis mucronatis, marginibus superioribus membranaceis; perianthio oblongo glabro; segmentis exterioribus lanceolatis acutis cartilagineis; segmentis interioribus membranaceis; spiculis femineis solitariis cuneato-oblongis 1-floris; bracteis ovato-lanceolatis mucronatis cartilagineis, marginibus

superioribus late membranaceis; perianthio oblongo glabro; segmentis exterioribus lanceolatis cartilagineis; segmentis interioribus ovato-lanceolatis bifidis membranaceis; ovario uniloculari; stylis tribus.

Stems about 30 cm. high, moderately branched, slender, terete, wrinkled, with brown iridescence. Sheaths rather loosely convolute, mostly 7–9 mm. long, oblong, obtuse, mucronate, coriaceous, broadly membranous at the upper margins, with a golden sheen. Male spikelets solitary, 5–6 mm. long, cuneate, containing 1 perfect flower. Spathe sheath-like, slightly more than half as long as the spikelet. Fertile bract about 5 mm. long, oblong-lanceolate, obtuse, mucronate, cartilaginous, broadly membranous at the upper margins, light brown. Perianth stipitate, about 3·5 mm. long, oblong, glabrous: outer segments alike, lanceolate, acute, dorsally rounded, cartilaginous: inner segments slightly shorter, ovate-lanceolate, toothed at the apex, membranous. Female spikelets solitary, 5–6 mm. long, cuneate-oblong, containing 1 perfect flower. Spathe sheath-like. Fertile bract ovate-lanceolate, mucronate, cartilaginous, widely membranous at the upper margins. Perianth stoutly stipitate, about 4 mm. long, oblong, glabrous: outer segments lanceolate, acute, cartilaginous: inner segments 2, slightly shorter, ovate-lanceolate, bifid, membranous. Ovary rotund, with 1 perfect chamber and the rudiments of 2 chambers. Styles 3, 1 distinctly the largest and free, 2 rudimentary and shortly united at base.

South Africa: Cape Province.—Caledon Div.: Somerset Sneeuwkop, alt. 4250 feet, March 12, 1937, *Stokoe* 5028*b* ♂ and ♀ (type, in Bolus Herbarium).

In superficial appearance this plant closely resembles *Leptocarpus intermedius* Pillans. It is related to *R. arcuatus* Mast., but is distinguished by its 1-flowered male spikelets, the acute outer segments of the perianth and the fusion of 2 of the styles at the base.

R. distans, sp. nov.; culmis ramosis gracilibus; vaginis arte convolutis obtusis mucronatis coriaceis; spiculis masculis rotundatis in cymas spicatas dispositis; bracteis ellipticis obtusis muticis vel mucronulatis; perianthio elliptico; segmentis lanceolatis obtusis, exterioribus lateralibus minute villosis; spiculis femineis cuneatis 2-floris in spicatas cymas dispositis; bracteis laxe imbricatis ovato-lanceolatis muticis coriaceis; perianthio oblongo glabro; segmentis lanceolatis obtusis; ovario uniloculari; stylis tribus liberis.

Stems 30–40 cm. high, sometimes decumbent at base, slender, somewhat wrinkled, moderately or much branched. Sheaths closely convolute, mostly 6–8 mm. long, very stoutly and obtusely mucronate, coriaceous, with deciduous membranous upper margins. Male spikelets several or many, widely separated in a spicate cyme, 4–7 mm. long, rotund. Spathe sheath-like, about half as long as the spikelet. Bracts erect-spreading, 3–4 mm. long, elliptic, obtuse, muticous or mucronulate, cartilaginous,

brown. Perianth much exposed, 2·5–3 mm. long, elliptic: outer segments lanceolate, obtuse, cartilaginous; the lateral navicular, minutely villous on the carina: inner segments lanceolate, obtuse, membranous. Female spikelets several or many, widely separated in a spicate cyme, cuneate, 5–6 mm. long, 2-flowered. Spathe sheath-like. Bracts loosely embracing the flowers, 4–5 mm. long, ovate-lanceolate, subacute, muticous, slightly curved sideways, coriaceous, brown. Perianth much exposed, 3·5–4 mm. long, slightly curved sideways, oblong, narrowed at base: outer segments lanceolate, obtuse, cartilaginous, glabrous; the lateral unequal, somewhat navicular: inner segments slightly shorter, linear-lanceolate, obtuse, membranous. Ovary obovate, 1-chambered. Styles 3, 2 adjacent, 1 isolated.

South Africa: Cape Province.—Caledon Div.: Hottentots Holland mountains, Landdrost Kop, alt. 4200 feet, July 1932, *Stokoe* 2712 ♂, Nov. 1934, 4016 ♂, 4017 ♀ (type, in Bolus Herbarium).

The affinity is with *R. arcuatus* Mast., but it differs in its stems not being curved several times as in that species, in the greater number of spikelets in a cyme, and in the differently shaped female spikelets.

R. Esterhuyseniae, sp. nov.; culmis ramosissimis gracilissibus teretibus tuberculatis; vaginis acuminatis aristatis coriaceis, marginibus membranaceis; spiculis masculis ovatis in cymas spicatas dispositis; bracteis ovatis acutis mucronatis cartilagineis, marginibus superioribus membranaceis; perianthio ovato; segmentis lanceolatis obtusis membranaceis, lateralibus villoso-carinatis; spiculis femineis solitariis vel geminatis ellipticis vel ovatis multi-floris; bracteis ut in mare; perianthio ovato; segmentis exterioribus oblongo-lanceolatis acutis, lateralibus villoso-carinatis; ovario biloculari; stylis duobus, basin connatis.

Stems about 50 cm. high, much branched, somewhat tangled, slender or filiform above the middle, terete, studded with well-spaced tubercles. Sheaths mostly 1·5–2 cm. long, closely convolute, acuminate, aristate, coriaceous, minutely tubercled, red-brown, pale-membranous at the margins. Male spikelets several or many in a lax spicate cyme, ovate, about 5 mm. long. Spathe sheath-like, smooth. Bracts ovate, acute, mucronate, cartilaginous, pale-membranous at the upper margins. Perianth about 2·75 mm. long, ovate, closely embraced by the bract: segments lanceolate, obtuse, membranous; the outer lateral villous-carinate. Female spikelets solitary or in pairs, about 5 mm. long, elliptic or ovate, several-flowered. Spathe sheath-like. Bracts closely embracing the flowers, ovate, acute, mucronate, coriaceous, membranous at the margins. Perianth about 4 mm. long, ovate: outer segments oblong-lanceolate, acute, cartilaginous; the lateral villous-carinate: inner segments slightly longer, lanceolate, acute, membranous. Ovary rotund, 2-chambered. Styles 2, united at base.

South Africa: Cape Province.—Ceres Div.: Baviaansberg, slopes above Karroo Poort, June 30, 1940, *Esterhuysen* 2573 ♂, 2574 ♀ (type, in Bolus Herbarium).

The affinity is with *R. vilis* Kunth, from which it differs by its more branched and more slender stems being studded with prominent well-spaced tubercles. It may be distinguished also by its much smaller and fewer-flowered spikelets.

R. filicaulis, sp. nov.: culmis simplicibus filiformibus teretibus; vaginis arte convolutis acutis mucronatis vel aristatis bilobis chartaceis; spiculis masculis solitariis obovatis; bracteis laxe convolutis ovatis acutis mucronatis cartilagineis, marginibus membranaceis; perianthio anguste ovato trigono glabro; segmentis exterioribus lineari-lanceolatis acutis cartilagineis; segmentis interioribus conspicue brevioribus obtusis membranaceis; spiculis femineis solitariis ut in mare 1–3-floris; bracteis ut in mare; perianthio anguste ovato trigono cartilagineo; segmentis exterioribus lanceolatis glabris, lateralibus acutis, anterioribus obtusis; segmentis interioribus brevioribus ovato-lanceolatis acutis; ovario trigono triloculari; stylis tribus liberis.

Stems about 25 cm. high, densely caespitose, simple, filiform, terete, wrinkled. Sheaths closely convolute, acute, mucronate or aristate, bilobed, mostly 0·6–1 cm. long without the appendage, chartaceous, nervose. Male spikelets solitary, 6–8 mm. long, obovate. Spathe ovate, acute, mucronate, chartaceous, much smaller than the bracts. Bracts erect-spreading, loosely clasping the flowers, about 4 mm. long, ovate, acute, mucronate, cartilaginous, membranous at the margins, light brown. Perianth 3 mm. long, narrowly ovate, unevenly trigonous, glabrous: outer segments linear-lanceolate, acute, cartilaginous; the lateral slightly carinate: inner segments distinctly shorter, lanceolate, obtuse, hyaline-membranous. Female spikelets solitary, resembling the male, 1–3-flowered. Bracts as in the male. Perianth 3 mm. long, narrowly ovate, trigonous, cartilaginous: outer segments lanceolate, glabrous; the lateral acute, carinate; the anterior obtuse, dorsally rounded: inner segments shorter, ovate-lanceolate, acute. Ovary rotund, trigonous, 3-chambered. Styles 3, adjacent.

South Africa: Cape Province.—Ceres Div.: near Michell's Pass, Slab Peak, Oct. 5, 1941, *Esterhuysen* 6194 ♂ and ♀ (type, in Bolus Herbarium).

The affinity is with *R. miser* Kunth, from which it differs by its more slender stems, much shorter acuter bracts and glabrous perianth.

R. fuscidulus, sp. nov.; culmis simplicibus teretibus rugulosis vel tuberculatis; vaginis laxe convolutis obtusis aristatis coriaceis, marginibus superioribus late membranaceis; spiculis masculis ovatis vel rotundatis fuscidulis; bracteis laxe imbricatis ovatis acutis coriaceis; perianthio obovato membranaceo; segmentis exterioribus linearibus, lateralibus

villoso-carinatis; segmentis interioribus conspicue brevioribus oblongis obtusis; spiculis femineis 1–2 rotundatis multi-floris; bracteis laxe imbricatis ovatis acutis fuscidulis; perianthio oblongo-elliptico; segmentis exterioribus lanceolatis acutis, lateralibus villoso-carinatis; segmentis interioribus paulum brevioribus ovato-lanceolatis obtusis; ovario biloculari; stylis duobus liberis.

Stems 30–40 cm. high, simple, wiry, terete, slightly rough with wrinkles or minute tubercles. Sheaths 1·5–2 cm. long, loosely convolute, obtuse, aristate, coriaceous, with a deciduous broadly membranous upper margin. Male spikelets usually 3–5 in a spicate cyme, ovate or rotund, 0·6–1 cm. long, chestnut-brown. Spathe ovate, sheath-like. Bracts loosely imbricate, about 5 mm. long, ovate, acute, mucronulate, coriaceous. Perianth shortly stipitate, about 3·5 mm. long, obovate, membranous: outer segments linear, acute; the lateral navicular, villous-carinate; the anterior glabrous: inner segments distinctly shorter, oblong, obtuse. Female spikelets 1 or 2, 1–1·5 cm. long, rotund, many-flowered. Spathe sheath-like, half as long as the spikelet. Bracts loosely imbricate, 0·9–1·3 cm. long, ovate, acute, mucronate, coriaceous, narrowly membranous at the margins, chestnut-brown. Perianth 5–6 mm. long, stoutly stipitate, oblong-elliptic: outer segments lanceolate, acute, cartilaginous; the lateral navicular, villous-carinate; the anterior glabrous: inner segments slightly shorter, ovate-lanceolate, obtuse, membranous. Ovary rotund, 2-chambered. Styles 2, adjacent, free. Seeds elliptic, longitudinally ridged.

South Africa: Cape Province.—Worcester Div.: Audensberg, summit, alt. 5600 feet, Oct. 6, 1940, *Esterhuysen* 3231 ♂, 3232 ♀ (type, in Bolus Herbarium).

The affinity is with *R. cuspidatus* Thunb. and *R. virgeus* Mast., from which it is distinguished by having differently arranged spikelets and broader flowers.

R. Galpinii, sp. nov.; culmis paulum ramosis teretibus; vaginis arte convolutis obtusis mucronatis coriaceis; spiculis masculis 1–3 obovatis vel rotundatis; bracteis ovatis acutis; perianthio elliptico; segmentis exterioribus lateralibus oblongis acutis villoso-carinatis; spiculis femineis 1–2 ellipticis multi-floris; bracteis ovatis acutis; perianthio elliptico; segmentis exterioribus lateralibus lanceolatis villoso-carinatis; ovario compresso biloculari; stylis tribus.

Stems 20–50 cm. high, moderately branched, wiry below the middle, slender above, terete, wrinkled. Sheaths closely convolute, obtuse, mucronate, coriaceous, narrowly cartilaginous at the margins, pale green, becoming red-brown. Male spikelets 1–3 in a spicate cyme, 4–9 mm. long, obovate or rotund, many-flowered. Spathe elliptic, mucronate, 4–6 mm. long without the mucro. Bracts loosely embracing the flowers, about 4 mm.

long, ovate, acute, mucronulate, cartilaginous. Perianth partly exposed at the sides, 3–4 mm. long, stipitate, elliptic: outer segments oblong, acute, cartilaginous; the lateral navicular, villous-carinate: inner segments slightly shorter, oblong-lanceolate, obtuse, membranous. Female spikelets 1–2 in a spicate cyme, about 1 cm. long, elliptic, many-flowered. Spathe elliptic, coriaceous, with a mucro reaching to near the middle of the spikelet. Bracts loosely embracing the flowers, 5–7 mm. long, ovate, acute, mucronulate, coriaceous. Perianth partly exposed at the sides, stipitate, 3·5–4 mm. long, elliptic: outer segments lanceolate, acute, coriaceous; the lateral villous-carinate: inner segments ovate, acute, cartilaginous. Ovary compressed, 2-chambered. Styles 3, adjacent.

South Africa: Cape Province.—Maclear Div.: Drakensberg, top of Tsitsa footpath, alt. *c.* 8400 feet, March 19, 1904, *Galpin* 6871 ♂. Natal Province—Weenen Div.: Drakensberg, near Cathkin Peak, alt. 8000 feet, July 1942, *Esterhuysen* 7921 ♂; between Cathkin Peak and Giant's Castle, alt. 7000–9000 feet, July 1943, *Esterhuysen* 8820 ♂ and ♀ (type, in Bolus Herbarium).

The affinity is with *R. sejunctus* Mast., from which it is distinguished by its fewer and larger spikelets, larger and entire bracts and the flowers being shorter than the bracts.

R. insignis, sp. nov.; culmis parce ramosis vel simplicibus teretibus paulum rigidis minute rugosis; vaginis arte convolutis acuminatis coriaceis; spiculis masculis 1–2 ovatis; bracteis arte imbricatis rotundatis obtusis coriaceis, marginibus superioribus membranaceis; perianthio elliptico; segmentis exterioribus lineari-lanceolatis obtusis, lateralibus villoso-carinatis; segmentis interioribus conspicue brevioribus; spiculis femineis bracteisque ut in mare; perianthio elliptico; segmentis obtusis cartilagineis; exterioribus lateralibus lineari-lanceolatis villoso-carinatis; segmentis interioribus conspicue brevioribus; ovario biloculari; stylis tribus basin connatis.

Stems about 50 cm. high, sparingly branched or simple, terete, wiry, minutely rugose. Sheaths mostly 1·5–2 cm. long, closely convolute, acuminate, mucronate, for the most part coriaceous, red-brown, speckled with grey, the apical portion broadly membranous and deciduous. Male spikelets 1–2, about 1·5 cm. long, ovate, obtuse, compact. Spathe sheath-like. Bracts closely imbricate, about 7 mm. long, rotund, obtuse, deeply concave, coriaceous, membranous at the upper margins, chestnut-brown. Perianth 6–7 mm. long, elliptic, exposed at the apex: outer segments linear-lanceolate, obtuse, cartilaginous; the lateral navicular, villous-carinate; the anterior glabrous: inner segments much shorter, lanceolate, membranous. Female spikelets, spathes and bracts as in the male. Perianth about 6 mm. long, stipitate, elliptic: segments obtuse, cartila-

ginous; the outer lateral linear-lanceolate, navicular, villous-carinate; the anterior ovate-lanceolate, glabrous: inner segments distinctly shorter, ovate-lanceolate. Ovary rotund, 2-chambered. Styles 3, united at base, thence diverging. Seeds rough with minute tubercles in longitudinal lines.

South Africa: Cape Province.—Clanwilliam Div.: Sneeuwkop, 1843, *Wallich* in British Museum and Kew herbaria ♂; Cederberg mountains, Langeberg, alt. 6000 feet, Dec. 15, 1941, *Esterhuysen* 7346 ♂ and ♀ (type, in Bolus Herbarium); Tafelberg, Sept. 25, 1942, *Stokoe* 8470 ♀. Worcester Div.: Matroosberg, middle of north slopes, Sept. 1924, *Levyns* 985 ♂.

The affinity is with *R. brunneus* Pillans, from which it is distinguished by fewer spikelets (those of the male much larger), muticous bracts, obtuse inner perianth segments of the female and by diverging styles.

R. nodosus, sp. nov.; culmis paulum ramosis teretibus tuberculatis; vaginis arte convolutis obtusis mucronatis, marginibus superioribus membranaceis deciduis; spiculis masculis 1–3 rotundatis; bracteis late ellipticis subacutis coriaceis; perianthio elliptico; segmentis exterioribus oblongo-lanceolatis acutis, lateralibus villoso-carinatis; segmentis interioribus conspicue brevioribus lanceolatis obtusis; spiculis femineis ut in mare pluri-floris; bracteis rotundatis; perianthio late rotundato; segmentis ut in mare; ovario biloculari; stylis tribus liberis.

Stems mostly 20–30 cm. high, moderately branched, wiry, terete, closely studded with flat-topped tubercles. Sheaths mostly 1–1·5 cm. long, closely convolute, obtuse, stoutly mucronate, becoming acute with the falling of the membranous upper margins. Male spikelets 1–3, spaced at the end of a branch, 0·8–1·2 cm. long, rotund. Spathe sheath-like, inconspicuous. Bracts closely imbricate, about 5 mm. long, broadly elliptic, subacute, coriaceous, chestnut-brown at the upper margins. Perianth about 4 mm. long, elliptic: outer segments oblong-lanceolate, acute, cartilaginous; the lateral amply villous-carinate: inner segments much shorter, lanceolate, obtuse, membranous. Female spikelets resembling the male, many-flowered. Bracts as in the male but rotund. Perianth 5 mm. long, broadly elliptic or rotund: segments as in the male. Ovary rotund, 2-chambered. Styles 3, separated.

South Africa: Cape Province.—Worcester Div.: Waaihoek, alt. 5000 feet, Dec. 16, 1942, *Esterhuysen* 8366 ♂ and ♀ (type, in Bolus Herbarium); Hex River mountains, Buffelshoek Peak, alt. 6000 feet, Dec. 25, 1942, *Esterhuysen* 8425 ♂, March 8, 1943, 8745 ♂; Milner Peak, alt. 5000–6000 feet, March 7, 1943, *Esterhuysen* 8717 ♂ and ♀; Fonteintjesberg, alt. 5000–6000 feet, March 9, 1943, *Esterhuysen* 8764 ♀.

This species greatly resembles *R. obscurus* Pillans but is easily distinguished by its tubercled stems. The affinity is with *R. strobilifer* Kunth,

from which it differs by its broader spikelets containing more flowers, and by its separated styles.

R. pygmaeus, sp. nov.; culmis simplicibus vel paulum ramosis gracilibus teretibus minute tuberculatis; vaginis laxe convolutis acutis, margine bilobo; spiculis masculis cuneatis 2–4-floris; bracteis oblongo-lanceolatis mucronatis coriaceis, marginibus superioribus membranaceis deciduis; perianthio cuneato membranaceo glabro; segmentis exterioribus lateralibus lineari-lanceolatis acutis; segmentis interioribus similibus; spiculis femineis ut in mare 2–3-floris; bracteis ut in mare; perianthio cartilagineo glabro; segmentis extus scabridis, exterioribus lateralibus ovato-lanceolatis, interioribus conspicue brevioribus ovatis acutis; ovario biloculari; stylis duobus breviter connatis.

Stems mostly 7–10 cm. high, simple or sparingly branched, slender, terete, closely and minutely tubercled. Sheaths mostly 6–8 mm. long, loosely convolute, acute, mucronate, coriaceous, scabrid, red-brown, with the upper margins produced into a pair of deciduous obtuse lobes. Male spikelets several in a spicate cyme, 4–6 mm. long, cuneate, 2–4-flowered. Spathe almost as long as the spikelet, sheath-like. Bracts about 4 mm. long, oblong-lanceolate, mucronate, coriaceous, with deciduous membranous upper margins. Perianth 3–3·5 mm. long, cuneate, membranous, glabrous: outer lateral segments linear-lanceolate, acute; the anterior linear: inner segments almost as long, similar. Female spikelets 2–5 in a spicate cyme, resembling the male, 2- or 3-flowered. Spathe and bracts as in the male. Perianth 3 mm. long, cartilaginous, glabrous: segments scabrid on the outer surface: the outer lateral navicular, ovate-lanceolate, mucronulate, membranous at the upper margins; the anterior lanceolate, acute: inner segments distinctly shorter, ovate, acute. Ovary rotund, compressed, 2-chambered. Styles 2, shortly united. Fruit 2- or, by abortion, 1-seeded. Seeds very coarsely tubercled.

South Africa: Cape Province.—Worcester Div.: Hex River mountains, Milner Peak, west aspect, rock surfaces and ledges, alt. 6000 feet, March 7, 1943, *Esterhuysen* 8710 ♂ and ♀ (type, in Bolus Herbarium); Buffelshoek area, alt. 6000 feet, Dec. 26, 1942, *Esterhuysen* 8415*a* ♂.

This is very distinct from all other species in the 2-styled group. It resembles *R. curviramis* Kunth superficially, but differs by the acute coriaceous upper portion of the leaf-sheaths, the 2- or 3-flowered spikelets, the glabrous perianth and the coarsely tubercled seeds.

R. subcompressus, sp. nov.; culmis intricatis ramosissimis gracilissimis paulum compressis; vaginis arte convolutis subacutis coriaceis; spiculis masculis cuneatis 2–4-floris; bracteis ovatis acutis cartilagineis; perianthio oblongo; segmentis anguste oblongo-lanceolatis obtusis membranaceis glabris; spiculis femineis solitariis cuneatis 1-floris; bractea solitaria ovata

mucronata cartilaginea; perianthio oblongo membranaceo; segmentis exterioribus lanceolatis acutis, lateralibus villoso-carinatis; segmentis interioribus conspicue brevioribus lanceolatis obtusis; ovario biloculari; stylis tribus basin connatis.

Stems 20–30 cm. high, crowded and tangled, much branched, very slender, somewhat compressed, minutely pitted. Sheaths closely convolute, lanceolate, subacute, coriaceous, light brown, 7–8 mm. long with the stout mucro. Male spikelets 1–3 in a spicate cyme, cuneate, 5–6 mm. long, laxly 2- or 3-flowered. Spathe about 4 mm. long, ovate, subulate-mucronate. Bracts 3–4 mm. long, ovate, acute, cartilaginous. Perianth subsessile, 3–4 mm. long, oblong: segments almost equal in length, narrowly oblong-lanceolate, obtuse, membranous, glabrous; the outer lateral somewhat navicular. Female spikelets solitary, about 5 mm. long, cuneate, 1-flowered. Spathe sheath-like, almost equalling the spikelet. Bract solitary, about 4 mm. long, ovate, mucronate, cartilaginous. Perianth stipitate, 4 mm. long, oblong, membranous: outer segments lanceolate, acute; the lateral villous-carinate: inner segments distinctly shorter, lanceolate, obtuse. Ovary rotund, 2-chambered. Styles 3, united at base and forming a short column, thence diverging. Seeds rotund, longitudinally striate, grey.

South Africa: Cape Province.—Caledon Div.: Hottentots Holland mountains, Landdrost Kop, marsh at the south-west base of the peak, alt. 3500 feet, Dec. 1939, *Esterhuysen* 3601 ♂ and ♀ (type, in Bolus Herbarium); Somerset Sneeuwkop, *Stokoe* 7659 ♂ and ♀.

Closely related to *R. depauperatus* Kunth, but distinguished by all parts being larger, by the obtuse perianth segments of the male, by the less tapered segments of the female perianth, and by the partly united styles.

R. echinatus Kunth, Enum., iii, 384 (1841), male plant only.

Female spikelets 1–3 in a spicate cyme, elliptic, 0·7–1·2 cm. long, many-flowered. Spathe broadly ovate, acuminate, stoutly mucronate, coriaceous, broadly membranous at the margins. Bracts erect-spreading, about 9 mm. long, ovate, acuminate, mucronate, coriaceous, membranous at the margins. Perianth stipitate, about 6 mm. long, elliptic: outer segments lanceolate, acute, coriaceous; the lateral navicular, villous-carinate; the anterior glabrous: inner segments much shorter, ovate-lanceolate, obtuse, cartilaginous. Ovary rotund, 2-chambered. Styles 3, adjacent, free. Seeds elliptic, angular, longitudinally striate.

South Africa: Cape Province.—Stellenbosch Div.: Somerset Sneeuwkop, west slopes, alt. 4500 feet, Dec. 1939, *Esterhuysen* 3586 ♂ and ♀ (type of female, in Bolus Herbarium). Worcester Div.: Pic Blanc, north-east slopes, alt. 3000 feet, Jan. 2, 1943, *Esterhuysen* 8508 ♂ and ♀.

This species was founded by Kunth on Drège's collecting of the male

plant in Du Toit's Kloof either in 1827 or 1833. The female plant was collected first in 1939.

R. Harveyi Mast. in Journ. Linn. Soc., viii, 253, tab. 15 (1865), female plant only.

Male spikelets solitary, terminal, 2·5–4 mm. long, elliptic or rotund, laxly 2- or 3-flowered. Spathe ovate, obtuse, coriaceous, hyaline-membranous at the margins, with a stout mucro reaching to the middle of the spikelet. Bracts (sometimes absent from the lowest flower) 2–2·5 mm. long, ovate, obtuse, mucronulate, coriaceous, pale-membranous at the margins. Perianth mostly exposed, 1·75–2 mm. long, stipitate, cuneate, membranous, glabrous: outer lateral segments linear-oblanceolate or oblong, obtuse, navicular; the anterior linear or oblong, acute or obtuse: inner segments oblong, obtuse.

South Africa: Cape Province.—Cape Div.: near Hout Bay, lower north-west slopes of Skoorsteen Kop, gravelly soil, flowering April 1940, *Pillans* 9822 ♂ (type of male, in Bolus Herbarium). Stellenbosch Div.: Somerset West, gravelly clay, March 26, 1940, *Parker* 3473 ♂ and ♀.

This species had been only known by Harvey's collecting of the female plant "near Cape Town" between 1835 and 1840.

R. Mahoni Pillans, comb. nov.: **Hypolaena Mahoni** N. E. Br. in Fl. Trop. Afr., vii, 265 (1901); Pillans in Trans. Roy. Soc. S. Afr., xvi, 398 (1928).

Stems of the female plant as in the male. Sheaths with broad membranous upper margins. Spikelets solitary, 0·8–1 cm. long, cuneate, several-flowered. Spathe sheath-like. Bracts 6–8 mm. long, loosely embracing the flowers, lanceolate, mucronulate, coriaceous, membranous at the upper margins. Perianth stipitate, about 4 mm. long, oblong, trigonous, cartilaginous, glabrous: outer segments lanceolate; the lateral very acute, somewhat carinate: inner segments slightly shorter, ovate-lanceolate, acute. Ovary rotund, 2-chambered, with prominent lateral sutures. Styles 3, widely spaced.

Tropical Africa: Belgian Congo.—Mount Muhi, alt. 10,200–10,425 feet, July 1942, *F. J. Hendrickx* ♀ (in Bolus Herbarium).

This species was founded on and hitherto only known by a male plant collected by Mahon at Zomba, Nyasaland, in 1898.

Chondropetalum *Rottb.*

C. Esterhuyseniae, sp. nov.; culmis simplicibus; vaginis acutis chartaceis deciduis; inflorescentia feminea paniculato-cymosa anguste oblonga densa; spathis persistentibus lanceolatis chartaceis; spiculis rotundatis; bracteis lanceolatis attenuatis pallido-membranaceis; peri-

anthio ovato cartilagineo; segmentis exterioribus ovatis, lateralibus acutis carinatis; segmentis interioribus duplo longioribus acutis; ovario trigono triloculari; stylis tribus.

Stems about 50 cm. high, simple, wiry, slightly wrinkled. Sheaths deciduous, about 2·5 cm. long, ovate-lanceolate, acute, mucronate, expanded, chartaceous, light brown. Female inflorescence 10–12 cm. long, paniculate-cymose, narrowly oblong, dense. Spathes peristent, mostly 3–3·5 cm. long, lanceolate, acute, mucronate, chartaceous, light brown. Spikelets terminal or axillary, mostly hidden, about 5 mm. long, rotund, few- or many-flowered. Bracts 0·8–1 cm. long, lanceolate, long-attenuate, pale-membranous, with a rigid brown midrib. Perianth subsessile, ovate, 3 mm. long, cartilaginous, chestnut-brown: outer segments ovate; the anterior obtuse; the lateral acute, carinate: inner segments twice as long, ovate, acute. Ovary rotund, trigonous, 3-chambered. Styles 3.

South Africa: Cape Province.—Stellenbosch Div.: Sneeuwkop, west slopes, alt. 4000 feet, Dec. 13, 1942, *Esterhuysen* 8219 ♀ (type, in Bolus Herbarium).

The affinity is with *C. paniculatum* Pillans, from which it is easily distinguished by much smaller female flowers with the inner segments twice as long as the outer.

C. longiflorum, sp. nov.; culmis simplicibus gracilibus; vaginis deciduis acutis coriaceis valde mucronatis; spiculis masculis orbicularibus in spicatas cymas dispositis; spathis persistentibus; bracteis ovatis acuminatis aristatis; perianthio ovato; segmentis exterioribus ovatis acutis; segmentis interioribus duplo longioribus ovato-lanceolatis acutis apiculatis; spiculis femineis rotundatis vel orbicularibus in spicatas cymas dispositis; bracteis ut in mare; perianthio ovato-lanceolato; segmentis exterioribus ovato-lanceolatis acutis; segmentis interioribus duplo longioribus; ovario triloculari; stylis tribus.

Stems about 50 cm. high, simple, slender-wiry, wrinkled. Sheaths deciduous, elliptic, acute, stoutly mucronate, coriaceous, light brown. Male spikelets 3–8 crowded in a spicate cyme, orbicular, 0·7–1·5 cm. long, many-flowered. Spathe persistent, sheath-like. Bracts erect-spreading, 0·8–1 cm. long, ovate, acuminate, aristate, dark brown. Perianth mostly exposed, 6 mm. long, ovate, somewhat dorsally compressed, chestnut-brown: outer segments ovate, acute; the lateral sharply carinate: inner segments twice as long, ovate-lanceolate, acute, apiculate, dorsally rounded. Female spikelets 1–5 crowded in a spicate cyme, rotund or orbicular, many-flowered, about 1·5 cm. long. Spathe and bracts as in the male. Perianth mostly exposed, about 1 cm. long, ovate-lanceolate, trigonous, coriaceous, chestnut-brown: outer segments ovate-lanceolate, acute, membranous at the margins; the lateral navicular, apiculate, sharply carinate: inner

segments twice as long, ovate-lanceolate, apiculate. Ovary rotund, trigonous, 3-chambered. Styles 3.

South Africa: Cape Province.—Ceres Div.: near Michell's Pass, Slab Peak, alt. 4000 feet, Oct. 5, 1941, *Esterhuysen* 6215 ♂ and ♀ (type, in Bolus Herbarium). Worcester Div.: between Waaihoek Peak and Mount Superior, amongst rocks, alt. 5000 feet, Dec. 5, 1942, *Esterhuysen* 8356 ♂ and ♀.

The affinity is with *C. nitidum* Pillans, from which it is distinguished by the much longer female inflorescence, by the larger spathes, shorter perianth, and less attenuated inner segments.

Elegia *Linn.*

E. altigena, sp. nov.: culmis simplicibus gracilibus; vaginis caducis; inflorescentia mascula paniculato-cymosa; bracteis orbicularibus membranaceis; perianthio rotundato; segmentis ellipticis obtusis; inflorescentia feminea lineari-oblonga; spathis persistentibus; bracteis minutis deltoideis; perianthio elliptico trigono membranaceo; segmentis exterioribus lineari-lanceolatis apiculatis; segmentis interioribus oblongo-lanceolatis obtusis; ovario dorse compresso, summa dura; stylis duobus brevibus.

Stems about 50 cm. high, slender-wiry, simple, terete, solid, smooth. Sheaths deciduous. Male inflorescence 4–7 cm. long, narrowly paniculate-cymose, with 2 or 3 simple or compound branches at each node. Spathes persistent, 1·5–2·5 cm. long, ovate-lanceolate, acute, expanded, chartaceous, rigid at base, pale red-brown. Spathellae inconspicuous, linear-lanceolate, membranous. Flowers in small clusters. Bracts about 1·5 mm. long, orbicular, membranous. Perianth sessile, about 2·5 mm. long, rotund, cartilaginous, red-brown: outer segments broadly elliptic, obtuse, deeply concave, slightly carinate: inner segments almost twice as long, elliptic-obovate, obtuse. Female inflorescence 4–6 cm. long, spicate-cymose, linear-oblong, with 1 or 2 short simple branches at each node. Spathes persistent, slightly convolute, otherwise as in the male. Flowers 2–4 at each node, 1 sessile. Spathellae absent. Bracts minute, deltoid, membranous. Perianth 3 mm. long, elliptic, trigonous, membranous: outer segments linear-lanceolate, apiculate, carinate: inner segments as long as the outer, oblong-lanceolate, obtuse. Ovary ovate, dorsally compressed, surmounted by a narrower horny cap. Styles 2, short, stout, recurved.

South Africa: Cape Province.—Uniondale Div.: Kamanassie mountains, Mannetjieberg, south slopes, alt. 6000 feet, Nov. 5, 1941, *Esterhuysen* 6399 ♂ and ♀ (type, in Bolus Herbarium).

The plants resemble smaller forms of *E. juncea* Linn., but the female is easily distinguished by its considerably fewer and much larger flowers, by the pronounced horny cap on the ovary and by the styles being only 2.

E. amoena, sp. nov.; culmis simplicibus paulum rigidis teretibus; vaginis deciduis oblongo-lanceolatis chartaceis; inflorescentia mascula paniculato-cymosa; bracteis minutis ovatis; perianthio rotundato membranaceo; segmentis exterioribus ovatis acutis; segmentis interioribus rotundatis exterioribus duplo longioribus; inflorescentia feminea spicato-cymosa; bracteis ut in mare; perianthio elliptico; segmentis exterioribus lineari-oblongis acutis valde carinatis; segmentis interioribus paulum brevioribus oblanceolatis subacutis; ovario dorse compresso, summa dura fissa; stylis duobus brevibus.

Stems about 60 cm. high, caespitose, simple, wiry, terete, solid, smooth. Sheaths deciduous, 3–4·5 cm. long, oblong-lanceolate, more or less convolute, mucronulate, chartaceous, buff, tinted red-brown. Male inflorescence 4–6 cm. long, paniculate-cymose, with 2 many-flowered simple or compound branches at each node. Spathes sheath-like, expanded, red-brown. Spathellae few, 2–4 mm. long, ovate, cuspidate, membranous. Bracts separated by a space of 1 mm. on the scorpioid rhaches, minute, ovate, membranous. Perianth stipitate, 2·5–2·75 mm. long, rotund, membranous, red-brown: outer segments ovate, acute, minutely carinate: inner segments twice or slightly more as long, rotund, obtuse or subacute, deeply concave. Female inflorescence spicate-cymose, 4–6 cm. long. Spathes as in the male, convolute in the lower half. Flowers hidden by the spathes, 1–3 at each node of the axis, sessile or pedunculate. Bracts as in the male. Perianth about 4 mm. long, elliptic, trigonous: outer segments linear-oblong, acute, navicular, prominently carinate, cartilaginous, membranous at the margins: inner segments slightly shorter, oblanceolate, subacute, membranous. Ovary elliptic, dorsally compressed, narrowed at the summit, surmounted by a narrower horny cap with lateral fissures. Styles 2, short, stout.

South Africa: Cape Province.—Paarl Div.: Witteberg, summit, alt. 6000 feet, Feb. 9, 1943, *Esterhuysen* 8660 ♂ and ♀ (type, in Bolus Herbarium).

A distinct species easily distinguished by its simple stems from all others with 2 styles. In general appearance it closely resembles *E. juncea* Linn.

E. bella, sp. nov.; culmis simplicibus teretibus paulum rigidis; vaginis deciduis lanceolatis chartaceis, marginibus pallido-membranaceis; inflorescentia mascula paniculato-cymosa; bracteis minutis deltoideis; perianthio ovoideo; segmentis exterioribus ovatis acutis membranaceis; segmentis interioribus duplo longioribus rotundatis; inflorescentia feminea spicato-cymosa; bracteis minutis; perianthio oblongo; segmentis exterioribus lineari-lanceolatis acutis conspicue carinatis; segmentis interioribus aequalibus oblongo-lanceolatis obtusis; ovario elliptico dorse compresso, summa dura fissa; stylis tribus.

Stems about 50 cm. high, simple, terete, solid, wiry. Sheaths deciduous, mostly 4–5 cm. long, lanceolate, acute, rigidly chartaceous, red-brown, pale-membranous at the margins. Male inflorescence about 8 cm. long, paniculate-cymose. Spathes 2·5–4 cm. long, sheath-like, expanded. Spathellae inconspicuous, membranous. Bracts minute, deltoid. Perianth 3 mm. long, ovoid, red-brown: outer segments ovate, acute, with a prominent midrib, membranous: inner segments slightly more than twice as long, rotund, obtuse, deeply concave, cartilaginous, membranous at the margins. Female inflorescence 5–7 cm. long, spicate-cymose. Spathes convolute in their lower parts, otherwise as in the male. Spathellae absent. Flowers hidden by the spathes, 3 or 4 to a spathe, all except 1 on branches. Bracts minute. Perianth 4·5–5 mm. long, oblong, trigonous: outer segments linear-lanceolate, acute, navicular, prominently carinate, cartilaginous, membranous at the sides: inner segments as long as the outer, oblong-lanceolate, obtuse, membranous. Ovary elliptic, dorsally compressed, surmounted by a narrower horny cap with 2 lateral fissures. Styles 2, short, stout.

South Africa: Cape Province.—Uniondale Div.: Helpmekaar Peak, Jan. 27, 1941, *Esterhuysen* 4583 ♂ and ♀ (type, in Bolus Herbarium).

The plant closely resembles *E. racemosa* Pers., but is more slender and has longer female flowers with narrower segments.

E. Esterhuyseniae, sp. nov.; culmis simplicibus gracilibus teretibus vel paulum compressis papillato-rugulosis; vaginis caducis mucronatis chartaceis; inflorescentia mascula paniculato-cymosa; bracteis minutis late ovatis; perianthio ovato chartaceo; segmentis exterioribus ovatis acuminatis; segmentis interioribus duplo longioribus ovatis acutis; inflorescentia feminea spicato-cymosa; perianthio oblongo; segmentis oblongo-lanceolatis acutis subaequalibus; exterioribus paulum carinatis; ovario oblongo, summa dura; stylis tribus.

Stems 30–40 cm. high, on creeping rhizomes, slender-wiry, simple, terete or slightly compressed when dried, solid, papillate-rugulose. Sheaths caducous, 3·5–4 cm. long, mucronate, chartaceous, red-brown. Male inflorescence 4–5 cm. long, paniculate-cymose. Spathes sheath-like, expanded. Bracts minute, broadly ovate, membranous. Perianth shortly stipitate, about 3·5 mm. long, ovate, chartaceous: outer segments ovate, acuminate: inner segments twice as long, ovate, acute. Female inflorescence 4–5 cm. long, spicate-cymose. Spathes convolute, otherwise as in the male. Flowers hidden, 1 or, less often, 2 in the axil of a spathe, 1 sessile. Perianth 6–7 mm. long, oblong, somewhat dorsally compressed: segments oblong-lanceolate, acute, dorsally rounded, subequal: the outer slightly carinate, cartilaginous, pale: the inner coriaceous, brown. Ovary

oblong, slightly compressed, surmounted by a narrower horny cap. Styles 3, separated, stout at base.

South Africa: Cape Province.—Clanwilliam Div.: Cederberg mountains, Langeberg, south-west slopes, alt. 5500 feet, Dec. 15, 1941, *Esterhuysen* 7353 ♂ and ♀ (type, in Bolus Herbarium). Worcester Div.: Du Toit's Peak, south-west slopes, alt. 6000 feet, Jan. 26, 1943, *Esterhuysen* 8555 ♂ and ♀.

A distinct species with stems resembling those of the more slender forms of *E. juncea* Linn., and the male inflorescence resembling that of *E. Neesii* Mast. The female inflorescence belongs to the type produced by *E. juncea*, but the flowers resemble those of *E. Neesii*.

Var. β, dispar: male plant having the perianth segments often obtuse, and the inner more than twice as long as the outer. Female flowers 5–5·5 mm. long: outer segments ovate: inner segments distinctly longer than the outer, elliptic, obtuse or subacute.

Cape Province.—Worcester Div.: Hex River mountains, Shale Peaks, alt. 6000 feet, Dec. 26, 1942, *Esterhuysen* 8451 ♂ and ♀ (type, in Bolus Herbarium); Mount Brodie, alt. 5000 feet, March 8, 1943, *Esterhuysen* 8760 ♀.

Leptocarpus *R. Br.*

L. Esterhuyseniae, sp. nov.; culmis simplicibus paulum rigidis, basin versus tuberculatis; vaginis arte convolutis ovatis acutis aristatis coriaceis, marginibus deciduis membranaceis; spiculis masculis ovatis vel rotundatis in spicatas vel paniculatas cymas dispositis; bracteis rotundatis cartilagineis; perianthio obovato; segmentis exterioribus oblanceolatis obtusis, lateralibus minute setaceo-carinatis vel glabris; segmentis interioribus lanceolatis obtusis; spiculis femineis ut in mare multi-floris; perianthio elliptico; segmentis exterioribus lineari-lanceolatis late carinatis; ovario elliptico vel obovato; stylis duobus liberis vel paulum connatis.

Stems 30–40 cm. high, simple, wiry, terete, slightly rough with flat-topped tubercles on the lower parts. Sheaths closely convolute, ovate, acute, coriaceous, chestnut-brown, speckled with yellow on the lower half, with broad membranous deciduous margins, 1·5–2 cm. long including the slender awn. Male spikelets 1–4 in a spicate cyme, or more in a slightly branched cyme, mostly 5–8 mm. long, ovate or rotund, obtuse. Spathe sheath-like. Bracts closely imbricate, 3·5–4 mm. long, rotund, obtuse, deeply concave, cartilaginous, chestnut-brown. Perianth 3·5–4 mm. long, shortly stipitate, partly exserted, obovate, very compressed, widely rounded at the upper end: outer segments narrowly oblanceolate, obtuse, cartilaginous; the lateral navicular, minutely and sparsely setaceous on the carina or glabrous; the anterior almost flat, glabrous: inner segments as long as

the outer, lanceolate, obtuse, membranous. Female spikelets resembling the male, sometimes more in number and then in a branched cyme, often acute, many-flowered. Spathe and bracts as in the male. Perianth subsessile, 3·5–4 mm. long, elliptic, very compressed, glabrous: outer lateral segments linear-lanceolate, acute, cartilaginous, with a wide keel excurrent on the short stipe; anterior segment linear-lanceolate, acute, membranous: inner segments almost as long, lanceolate, acute, membranous. Ovary elliptic or obovate, compressed, 1-chambered. Styles 2, adjacent, free or shortly united. Seeds elliptic, compressed, smooth.

South Africa: Cape Province.—Paarl Div.: upper Wellington Sneeuwkop, alt. 4000–5000 feet, Feb. 8, 1943, *Esterhuysen* 8658 ♂; Witteberg, shale band at the base, east aspect, alt. 4500 feet, Feb. 9, 1943, *Esterhuysen* 8659 ♂ and ♀. Ceres Div.: Slab Peak, south-east slopes, alt. 4000 feet, Oct. 6, 1941, *Esterhuysen* 6211 ♂ and ♀ (type, in Bolus Herbarium); Bokkeveld Tafelberg, south-east slopes, alt. 4500 feet, Dec. 8, 1940, *Esterhuysen* 3902 ♂ and ♀. Worcester Div.: Zebasberg, north-east slopes, alt. 5500 feet, Dec. 16, 1942, *Esterhuysen* 8371 ♀; Chavonnesberg, south-east slopes, alt. 4000–5000 feet, Oct. 4, 1942, *Esterhuysen* 8179 ♂ and ♀; Pic Blanc, north-east slopes, Jan. 1, 1943, *Esterhuysen* 8531 ♂ and ♀; Fonteintjiesberg, alt. 5000–6000 feet, March 9, 1943, *Esterhuysen* 8770 ♂ and ♀.

This is very distinct from all other African species of *Leptocarpus*, and is the second species in the genus to be discovered in Africa with 2 styles.

L. nudiflorus, sp. nov.; culmis ramosissimis gracilissimis tuberculatis; vaginis arte convolutis acutis; spiculis masculis cuneatis in spicatas cymas dispositis; bracteis lanceolatis acutis cartilagineis; perianthio oblique cuneato; segmentis exterioribus lineari-lanceolatis acutis cartilagineis glabris; segmentis interioribus conspicue brevioribus lineari-oblanceolatis obtusis; spiculis femineis cuneatis 1–2-floris 2–3 in spicatam cymam dispositis; bracteis lanceolatis acutis; perianthio oblongo trigono; segmentis exterioribus lineari-oblongis obtusis cartilagineis glabris; segmentis interioribus lineari-lanceolatis obtusis; ovario obovato; stylis tribus.

Stems mostly 20–30 cm. high, densely caespitose, much branched, very slender, 0·5 mm. thick at the middle, closely tubercled. Sheaths closely convolute, mostly 5–8 mm. long, acute, mucronate, coriaceous, with deciduous broad upper margins. Male spikelets several, well-spaced in a spicate cyme, cuneate, 5–8 mm. long, laxly few-flowered. Spathe sheath-like. Bracts 4–5 mm. long, lanceolate, acute, cartilaginous, light brown, pale-membranous at the upper margins. Perianth subsessile, 2·5–3 mm. long, obliquely cuneate: outer segments linear-lanceolate, acute, dorsally rounded, cartilaginous, glabrous: inner segments distinctly shorter, linear-oblanceolate, obtuse, membranous. Female spikelets 2 or 3, well-spaced

in a spicate cyme, cuneate, 4–5 mm. long, 1- or, less often, 2-flowered. Spathe sheath-like. Bracts 2 or 3, lanceolate, acute, 2·5–3·5 mm. long, cartilaginous, membranous at the apex, light brown. Perianth for the most part exposed, subsessile, about 2·5 mm. long, oblong, trigonous: outer segments linear-oblong, obtuse, dorsally rounded, cartilaginous, glabrous: inner segments almost as long, linear-lanceolate, obtuse, cartilaginous, membranous at the margins. Ovary obovate. Styles 3.

South Africa: Cape Province.—Caledon Div.: near Elgin, Nieuweberg, Sept. 1935, *Stokoe* 3181 ♂; Somerset Sneeuwkop, alt. 4000 feet, Dec. 13, 1942, *Esterhuysen* 8230 ♂ and ♀ (type, in Bolus Herbarium).

This species bears no close resemblance to any other recorded from Africa. If it has affinity with any known species it is probably with *L. impolitus* Pillans and *L. hyalinus* Pillans which have a similar type of inflorescence.

L. ramosissimus, sp. nov.; culmis ramosissimis rigidis minute tuberculatis; vaginis laxe convolutis obtusissimis mucronatis coriaceis; spiculis femineis cylindraceis pluri-floris 1–3 in spicatam cymam dispositis; bracteis arte convolutis rotundatis acutis mucronatis coriaceis, marginibus superioribus membranaceis; perianthio elliptico-oblongo membranaceo; segmentis exterioribus lineari-oblongis, lateralibus acutis paulum villoso-carinatis, anterioribus conspicue brevioribus; segmentis interioribus oblanceolatis obtusis; ovario elliptico compressissimo, summa dura; stylis tribus liberis.

Stems about 40 cm. high, rigidly wiry, very minutely tubercled, with 1 or 2 slender repeatedly divided branches at each node. Sheaths loosely convolute, rounded at the upper end, subulate-mucronate, coriaceous, chartaceous at the margins, red-brown, speckled with buff; those on the main stem about 1·5 cm. long; those on the branches 0·4–0·5 cm. long, often purplish on the upper margin. Male plant unknown. Female spikelets solitary or rarely 2 or 3, adjacent, 5–8 mm. long, cylindric, many-flowered. Spathe about 2·5 mm. long, orbicular, subulate-mucronate, coriaceous, broadly chartaceous at the margins, often purplish above the middle. Bracts closely imbricate, rotund, abruptly acute, 3 mm. long without the mucro, coriaceous, membranous at the upper margin, straw-coloured, red-brown at the apex. Perianth sessile, 2·75–3 mm. long, elliptic-oblong, rounded on the dorsal surface, membranous, pale straw-coloured: outer segments linear-oblong; the lateral slightly unequal in length, acute, slightly carinate, minutely puberulous on the upper half of the carina; the anterior much shorter, obtuse or acute, often toothed at the apex: inner segments slightly shorter than the outer lateral, oblanceolate, obtuse. Ovary elliptic much compressed, surmounted by a horny cap. Styles 3, adjacent, free.

South Africa: Cape Province.—Cape Div.: Karbonkelberg, Kapiteinspiek, south-east slope, alt. *c.* 700 feet, Oct. 26, 1940, *Kies* 201 ♀ (type, in Herbarium of National Botanic Gardens, Kirstenbosch).

The affinity is with *L. gracilis* Pillans, from which it is distinguished by much stouter stems, loosely convolute sheaths rounded at the upper margin, and by larger female spikelets with more flowers.

L. Stokoei, sp. nov.; culmis paulum ramosis basin versus rigidis; vaginis laxe convolutis acutis coriaceis, marginibus superioribus membranaceis; spiculis masculis cuneatis 2–3 in cymam spicatam dispositis; bracteis oblongis vel ovato-lanceolatis acutis coriaceis; perianthio oblique oblanceolato; segmentis lanceolatis cartilagineis, lateralibus acutis paulum carinatis, apice minute puberulis; spiculis femineis cuneatis 2 in cymam spicatam dispositis; bracteis ut in mare; perianthio oblique elliptico; segmentis exterioribus lanceolatis obtusis, lateralibus apice minute puberulis; ovario uniloculari; stylis tribus liberis.

Stems about 40 cm. high, moderately branched, wiry in the lower parts, slender in the upper, terete, almost smooth. Sheaths mostly 1–1·5 cm. long, loosely convolute, acute, mucronate, coriaceous, light brown, with deciduous membranous upper margins. Male spikelets 2 or 3 in a spicate cyme, cuneate, about 8 mm. long, few-flowered. Spathe sheath-like. Bracts loosely embracing the flowers, 4–6 mm. long, oblong or ovate-lanceolate, acute, coriaceous, narrowly membranous at the upper margins, red-brown. Perianth 2·5–3 mm. long, stoutly stipitate, partly exposed, obliquely oblanceolate: segments lanceolate, cartilaginous: the outer lateral unequal, navicular, acute, scarcely carinate, minutely puberulous about the apex; the anterior obtuse: inner segments lanceolate, obtuse, membranous. Female spikelets usually 2 in a spicate cyme, cuneate, about 8 mm. long, few-flowered. Spathe sheath-like. Bracts as in the male. Perianth partly exposed, stoutly stipitate, about 3 mm. long, obliquely elliptic: outer segments lanceolate, obtuse, cartilaginous; one of the lateral navicular, scarcely carinate, minutely puberulous about the apex; the anterior and one of the lateral dorsally convex: inner segments as long as the outer, lanceolate, obtuse, membranous. Ovary 1-chambered. Styles 3, free.

South Africa: Cape Province.—Caledon Div.: Somerset Sneeuwkop, alt. 4250 feet, March 12, 1937, *Stokoe* 5028*a* ♂ and ♀ (type, in Bolus Herbarium).

The affinity is with *L. intermedius* Pillans and *L. secundus* Pillans, from which it differs by its shorter and broader female perianth and by one of the outer segments being puberulous about the apex.

Thamnochortus *Berg.*

T. Comptonii sp. nov.; culmis simplicibus laevibus vel paulum rugosis; vaginis acutis supra medium chartaceis; spiculis masculis ellipticis; bracteis ovato-lanceolatis; perianthio elliptico membranaceo; segmentis oblongo-lanceolatis subacutis; spiculis femineis 1–2 obovatis vel rotundatis; bracteis lanceolatis acutis chartaceis; perianthio orbiculari chartaceo pallido; segmentis exterioribus lateralibus lineari-lanceolatis valde alatis; segmentis interioribus duplo brevioribus ovatis; ovario rotundato scabrido.

Stems 30–40 cm. high, simple, wiry, smooth or somewhat wrinkled or pitted. Sheaths 2·5–3 cm. long, acute, mucronate, chartaceous and pale above the middle. Male spikelets 6–8 mm. long, elliptic, erect or spreading, many in a panicle 3–5 cm. long. Bracts 4–5 mm. long, loosely embracing the flowers, ovate-lanceolate, mucronulate, cartilaginous, light brown, chartaceous and pale above the middle. Perianth 3–3·5 mm. long, elliptic, membranous: segments oblong-lanceolate, subacute. Female spikelets solitary or geminate, 1–1·5 cm. long, obovate or rotund. Bracts very loosely imbricate, 0·7–2 cm. long, lanceolate, acute, chartaceous, light brown, pale at the margins and apex. Perianth 5–6 mm. long, much exposed beyond the sides of the bracts, orbicular, chartaceous, pale, streaked with light brown, or light brown with pale margins: outer lateral segments linear-lanceolate, acute, with wings 1·5 mm. wide at or shortly below the middle, decurrent on the stipe; anterior segment much shorter, lanceolate, obtuse, narrowed towards the base: inner segments about half as long as the outer lateral (including the wings), ovate, obtuse or acute. Ovary rotund, scabrid, surmounted by a solitary style.

South Africa: Cape Province.—Clanwilliam Div.: Cederberg, Driehoek, alt. 3500 feet, Dec. 3, 1934, *Compton* 4731 ♂, 4733 ♀; Pakhuis, Sept. 29, 1940, *Esterhuysen* 3235 ♂, 3236 ♀; Middelberg plateau, Dec. 14, 1941, *Esterhuysen* 7193 ♂ and ♀ (type, in Bolus Herbarium), June 22, 1942, 7862 ♀.

The affinity is with *T. Stokoei* Pillans, from which it is easily distinguished by its very much larger female flowers with the inner segments much shorter than the outer lateral.

Hypolaena *R. Br.*

H. spathulata, sp. nov.; culmis ramosis infra medium rigidis supra medium paulum compressis; vaginis acutis striatis purpureo-brunneis; spiculis masculis rotundatis; bracteis ovatis acutis cartilagineis; perianthio imperfecto; segmentis lateralibus anguste linearibus obtusis; spiculis femineis oblanceolatis vel ovatis 1-floris 1–2 in cymam spicatam dispositis; bracteis ellipticis obtusis coriaceis; perianthio stipitato membranaceo vel

cartilagineo; segmentis exterioribus spathulatis vel obovatis obtusissimis apiculatis; segmentis interioribus 2, lateralibus lineari-spathulatis; ovario elliptico basin duro, apice duro; stylis duobus basin connatis.

Stems about 30 cm. high, much branched from near the base upwards, terete, wrinkled, wiry and terete below the middle, slender and somewhat compressed upwards. Sheaths 1–1·5 cm. long on the lower parts, about 0·5 cm. on the upper, closely convolute, oblong-lanceolate, acute, mucronate, coriaceous, striate, purple-brown. Male spikelets 2–5 in a lax spicate cyme, rotund, 5–7 mm. long, many-flowered. Spathes deciduous, about 7 mm. long, sheath-like. Bracts loosely imbricate, 4–5 mm. long, ovate, acute, apiculate, cartilaginous, buff-coloured, red-brown at the apex. Perianth imperfect, only the 2 outer lateral segments developed: segments 2 mm. long, diverging slightly, incurved above the middle, narrowly linear, obtuse, slightly widened above the middle, cartilaginous. Receptacle fleshy, pale. Female spikelets 1 or 2 in a spicate cyme, 8–10 mm. long, oblanceolate to obovate when in fruit, terete, 1-flowered. Spathe sheath-like. Bracts about 4, closely imbricate, elliptic, obtuse, 5–6 mm. long excluding the mucro, coriaceous, red-brown. Perianth on a trilobed fleshy stipe, 3–5 mm. long in the fruiting period, membranous, sometimes becoming cartilaginous: outer segments spathulate or obovate, very obtuse, apiculate: inner segments 2, lateral (apparently absent during the flowering period and developing with the growth of fruit), linear-spathulate, membranous, as long as the outer, adhering closely to the upper half of the fruit. Ovary elliptic, horny at base, surmounted by a horny cap. Styles 2, united at base. Fruit on a trilobed fleshy stipe, elliptic or ovate, black.

South Africa: Cape Province.—Uniondale Div.: Kouga mountains, peak east of Smutsberg, alt. 4000 feet, Nov. 27, 1941, *Esterhuysen* 6982 ♂ and ♀ (type, in Bolus Herbarium); Hoopsberg, south slopes, alt. 5000 feet, Nov. 6, 1941, *Esterhuysen* 6538 ♂ and ♀; Mannetjieberg, south slopes, alt. 5000 feet, Nov. 6, 1941, *Esterhuysen* 6411 ♂ and ♀; Joubertina, Nov. 30, 1941, *Esterhuysen* 7082 ♂ and ♀; Helpmekaar Peak, Jan. 28, 1941, *Esterhuysen* 4592 ♂ and ♀.

The affinity is with *H. purpurea* Pillans, to which it bears a close superficial resemblance. It is, however, easily distinguished by the trilobed stipe and the 2 well-developed spathulate inner segments of the female flower.

Willdenowia *Thunb.*

W. Esterhuyseniae, sp. nov.; culmis simplicibus laevibus; vaginis arte convolutis acutis aristatis coriaceis, marginibus membranaceis fimbrillatis; inflorescentia mascula paniculato-cymosa; bracteis linearibus acuminatis; perianthio elliptico; segmentis exterioribus linearibus acuminatis; seg-

mentis interioribus oblongo-lanceolatis; spiculis femineis 1–2-floris in cymas spicatas dispositis; bracteis lanceolatis acuminatis vel aristatis; perianthio stipitato; segmentis exterioribus subquadratis deltoideis vel oblongis obtusissimis apiculatis; segmentis interioribus aequalibus obovatis oblongis vel subquadratis obtusissimis apiculatis; stylis liberis.

Stems mostly 30–40 cm. high, 2–3 mm. thick at the middle, simple, smooth. Sheaths 2–4 cm. long, closely convolute, acute, aristate, coriaceous, buff-coloured on the lower half, chestnut-brown on the upper, with pale-membranous fimbrillate margins; the uppermost on the male plant obtuse, entirely chestnut-brown. Male inflorescence a dense oblong panicle 2·5–3·5 cm. long, with simple branches. Spathes 1 to an inflorescence, deciduous, somewhat expanded, ovate-lanceolate, aristate, coriaceous, chestnut-brown, fimbrillate towards the apex. Bracts about twice as long as the flowers, linear, acuminate, concave, membranous. Perianth stipitate, 4 mm. long, elliptic, tapered at base, dorsally compressed, membranous, pale: outer segments linear, acuminate, concave: the inner slightly shorter, oblong-lanceolate, acuminate. Female inflorescence a compact spicate cyme 4–5 cm. long, with 2 or 3 spikelets, each with 1 or 2 flowers. Spathes persistent, 2·5–3·5 cm. long, lanceolate, acute, aristate, coriaceous, chestnut-brown, fimbrillate about the apex. Bracts lanceolate or ovate-lanceolate, acuminate or aristate, cartilaginous, pale. Perianth 1·25–2 mm. long, on an angular fleshy stipe: segments separated or adjacent and imbricate at base, membranous; the outer broad-based, thence upwards subquadrate, deltoid or oblong, widely rounded at the upper margin, apiculate; the inner about as long, obovate, oblong or subquadrate, widely rounded, apiculate and usually retuse at the upper margin. Ovary not seen. Fruit broadly elliptic, flattened across the apex, very coarsely rugose. Styles free, with long stigmatic hairs from the base upwards.

South Africa: Cape Province.—Ceres Div.: near Michell's Pass, Slab Peak, alt. 4000 feet, Oct. 5, 1941, *Esterhuysen* 6212 ♂ and ♀ (type, in Bolus Herbarium). Paarl Div.: Witteberg, alt. 6000 feet, Feb. 9, 1943, *Esterhuysen* 8662 ♀. Worcester Div.: Hex River mountains, Shale Peaks, alt. 5000–6000 feet, Dec. 26, 1942, *Esterhuysen* 8640 ♀; Milner Ridge, alt. 5000 feet, March 7, 1943, *Esterhuysen* 8731 ♂ and ♀; near Bains Kloof, Cossacks, Feb. 7, 1943, *Esterhuysen* 8702 ♀.

The affinity is with *W. fimbriata* Kunth and *W. Stokoei* Pillans; differing from the former by its rugose fruit and entire stipe supporting the perianth and fruit, and from the latter by its stipitate perianth and rugose fruit.

CONSIDERATION OF THE SUCCESSIONAL THEORY AS APPLIED TO THE DENTITION OF *PAGRUS NASUTUS* (THE MUSSEL-CRUSHER) AND SOME REPTILES.

By F. Gordon Cawston.

(With two Text-figures.)

(Read September 8, 1943.)

Dissection of the jaw of *Pagrus nasutus* reveals reserve teeth in various stages of development lying in hollows deep to the functional teeth of both front and hinder rows, as may also be seen by radiographic examination. Occasionally these hollows are largely filled with bone and there is no sign of a reserve tooth, as though the hollow had either not formed or had become invaded by solid bone after replacement of a shed tooth by the reserve one (fig. 1).

Reserve teeth are formed in an almost complete row deep to the large outer row of teeth, which are mostly well anchylosed. There would seem to be no connection between the presence of a reserve tooth and anchylosis of the functional ones. Most of the root-portions of the latter are anchylosed so that the crown can easily be broken off. No indication of alternate anchylosis of teeth has been noted.

Professor M. R. Drennan notes that teeth without successors also show no foramina leading down to cavities containing the crowns of new teeth, as described by Richard Owen, and he considers that this absence of foramina indicates that eruption is complete. Drennan suggests that the foramina may cease to exist after the last shedding, just as human foramina disappear after eruption of the permanent set of teeth, and adds: "In the specimens you have dissected there is no indication of a continuous vertical succession such as Owen suggests. I consider that the succession is obviously limited to the one series of reserve teeth which you have exposed, in short, that each row is probably diphyodont."

This view is in conformity with the impression gained by a study of the dentition of the African Crocodile and the Indian Gavial (fig. 2), where the sequence of teeth would appear to be limited to three rows, the third remaining undeveloped, whilst the second serves for replacement only when one or more is shed from the exposed row.

J. R. Kinghorn explains the complete series of blunted and no newer sharper teeth in the jaws of very old crocodiles on the assumption that the succession of teeth does not persist indefinitely, but dissection and radio-

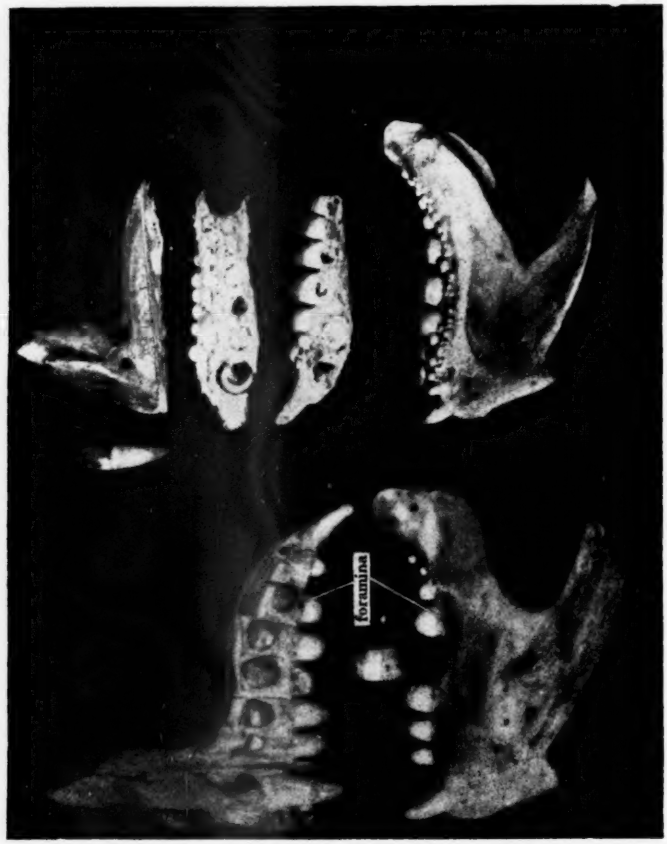
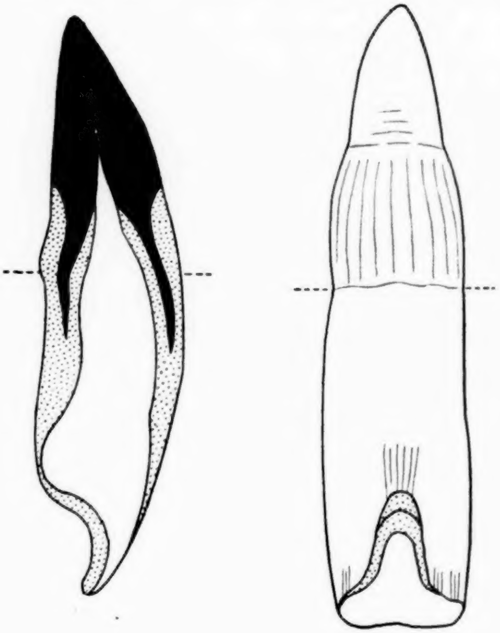


FIG. 1.—Photograph of the jaw of *Pagrus nasutus*, ½ natural size (approximately 3½ inches in length), showing the anchylosed exposed teeth and foramina leading down to the reserves. In one part of the jaw the small hinder reserve teeth have been exposed in cross-section, as has also part of the row of the large front reserves.

graphic examination shows that the third row of teeth is often incomplete, not only in immature specimens but in fully mature ones.

Failure to realise that the erupted teeth of a crocodile can continue

A



B

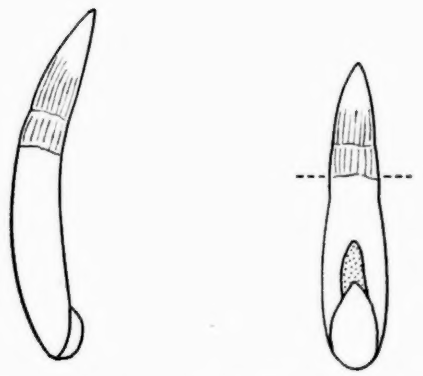


FIG. 2.—Diagrammatic representation of the composite character of the teeth of (A) *Crocodilus niloticus* Laurenti and (B) *Gavialis gangeticus* Laurenti, 7/10th natural size (the latter being $2\frac{3}{4}$ inches in length). The translucent portion of part of the lower portion of the crown and most of the root of the tooth of the Crocodile is well seen.

to grow after eruption has fostered the impression that they are provided with a continuous succession of teeth. The composite nature of their teeth would, however, explain this, for, although the crown of each tooth is coated with orthodentine which becomes worn but is incapable of further growth because of its invested cap of enamel, the root of each remains buried in the jaw and consists of vasodentine and cementum.

Thus the implanted root grows stouter close to the crown and gradually becomes coated with enamel as it erupts, whilst the root gradually extends deeper into the jaw round the open pulp chamber and becomes coated with cementum. This allows for continued increase in size of each tooth throughout the life of the crocodile or until the tooth is shed (fig. 2, A).

There has been a tendency to apply the theory of constant succession of teeth, as seen in a limited number of fishes, where vertical succession continues through life, too widely, and to expect what occurs in Man to be seen in other orders. Richard Owen's conception of an absorbent process which displaces the anchylosed functional teeth, so that "there is a free and constant succession of teeth in the phytiphagous Sargues" (that is to say, in some of the fishes) is untenable.

Nor can support be found for the view, which is sometimes held, that there are foramina leading down to successional teeth in some species of *Varanus* (the Iguana). Radiographic examination of the adult jaw of *Varanus niloticus* Laurenti, and the few minute teeth, loose in the gum behind the stout front line of teeth, may serve for reinforcing the bite but must not be mistaken for successional ones.

Recognition of the complete entity of teeth in various species should correct the tendency to apply the theory of endless vertical succession indiscriminately and should make investigators hesitate before describing any revolving of a tooth-bearing area, whether of periosteum or gum, to serve for replacement of shed teeth, especially in species which have no provision against such loss.

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REPORT ON THE EXCAVATIONS AT HYRAX HILL, NAKURU, KENYA COLONY, 1937–1938.*

By Mary D. Leakey.

With contributions by L. S. B. Leakey and P. M. Game.

(With Plates IX–XXIII, Plans I–III, and thirty-five Text-figures.)

(Communicated by A. J. H. Goodwin.)

(Read August 19, 1942.)

CONTENTS.

* The Government of Kenya Colony has contributed generously towards the cost of publication of this paper from the Coryndon Museum, Nairobi.

The position of Hyrax Hill is Long. 36° 6′ 3″ E.; Lat. 0° 16′ 8″ S.; and is indicated on the War Office Map of Africa, Sheet South A. 37.

LIST OF ILLUSTRATIONS.

PLATES.

FIGURES.

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PART I.

The Site.

Hyrax Hill is formed by a rocky spur, approximately half a mile in length, which stands 160 feet above the surrounding grassy plains. It is known locally as Hyrax Hill owing to the large numbers of these small animals which inhabit the clefts and crevices of the rocks. A quarter of a mile distant a similar kopje, formed by the same volcanic ash and lava, has at its foot the Nakuru Burial Site, excavated during 1926 (1). The prehistoric settlements and burials surrounding Hyrax Hill were first noted when this excavation was being carried out.

In April 1937 I visited the site, and thanks to the annual grass fires which had cleared the vegetation, it was possible to identify the settlements discovered during 1926. It was noticed that, in addition, groups of pit dwellings with accompanying mounds lay at the foot of the hill.

Excavations were begun in July on the series of stone-walled enclosures lying to the south-east of the hill and were subsequently extended to a low stony mound adjacent to the enclosures (Mound D). During 1938 excavations were also carried out in the group of pit dwellings lying at the north-east extremity of the hill.

The three principal areas of prehistoric occupation, are as follows:—

(1) Site I. The Neolithic occupation and cemetery together with the stone-walled enclosures, lying at the foot of the hill on the south-east.
(2) Site II. The village of pit dwellings at the north-east extremity of the hill, which may be assumed to belong to a phase of the Gumban B Variant of the Stone Bowl Culture.
(3) A similar group of pit dwellings clustered round the south-west extremity of the hill.

In addition to these main areas of habitation, a number of isolated pits and burials occur in the intervening areas and a stone circle or fort was discovered on top of the hill, north of the Survey beacon and situated in a defensive position.

The situation of the prehistoric settlements at Hyrax Hill is particularly fortunate from an archæological point of view, since the hill is low-lying in the Nakuru basin and the existence of the former epi-pluvial terraces and beaches of the lake, which may be traced on the slopes of the hill and in the surrounding district, provides valuable evidence as to the relative dating of the various settlements and to the periods during which the hill would be habitable by prehistoric man, who must necessarily have been dependent

for water supply upon the lake; no other sources being known in the vicinity of the hill.

Although it is unnecessary to recapitulate all the evidence obtained by investigators of the climatic changes which took place in the Nakuru basin during prehistoric times, the following notes are essential to an understanding of the results obtained during the excavations.

The areas of prehistoric occupation surrounding Hyrax Hill lie at a height of between 200 and 380 feet above the June 1929 lake level, upon which all figures are based, owing to the seasonable and annual fluctuation of the water. It is obvious, therefore, that the areas in question were submerged during the rise of the lake to 500 feet, which is believed to have taken place during the second phase of the Gamblian Pluvial and has been correlated with the existence of the Upper Kenya Aurignacian and Stillbay Cultures in the region (2).

The beach deposits and terraces caused by the 375 feet rise of the lake during the first peak of the Makalian Wet Phase may be clearly traced on Hyrax Hill and on the neighbouring kopje, on the slopes of which the Nakuru Burial Site is situated. No prehistoric occupation on Hyrax Hill is known to antedate this Makalian beach, which is hardly surprising, since during the maximum of the wet phase the hill would have formed a small rocky peninsula, jutting out into the waters of the lake and offering little inducement for human habitation.

A few rolled implements recovered from the 335-foot beach, which underlies the earliest known Neolithic settlement on the hill, may perhaps be contemporary with the rise of the lake during the oncoming of the Makalian Wet Phase, but before the maximum period had been reached. (These implements are described on p. 295.)

The second beach must be assigned to a rest level or slight oscillation during the recession of the Makalian lake and was formed, in all probability, not very long after the maximum period.

The beaches and terraces formed by the lake during the Nakuran Wet Phase, when it rose to 145 feet above the 1929 level, can be traced at a number of points in the plains below Hyrax Hill. The post-maximum Nakuran rest levels of the lake have also been located and studied by Dr. Nilsson.

Although the various workers in the field of East African Climatic Changes, such as Nilsson, Wayland, Reck, Solomon, Leakey and others, do not entirely agree regarding all the pluvial periods, the sequence of lake levels in the Nakuru Basin, briefly summarised above, seems sufficiently well established to justify its use as a basis for the relative dating of the successive prehistoric settlements on Hyrax Hill, which were unquestionably influenced by changing climatic conditions.

A further and more detailed survey of the Nakuru, Naivasha, and Elmenteita lake basins with especial regard to the correlation of archaeological and geological evidence would be most valuable.

The Excavations.

Permission to excavate at Hyrax Hill was kindly granted by Capt. G. Rickard, manager of the Nakuru Industries and of the Prairie Farm Estate. The cost of the excavation was largely sustained by donations from visitors to the site who most generously contributed over £100 and also by the Excavation Fund, inaugurated by Commander Couldrey, editor of the *Kenya Weekly News*, which amounted to £12, 8s. 0d.

I would like to express my thanks to all those who so generously supported the work; to the Headman, Hesron wa Gethua, whose untiring patience, skill, and "flair" deserve special mention; to Thairu wa Irumbi, to whom I am greatly indebted for his reliability and accuracy during the surveying, and to the other Africans for the months of steady work they put in, sometimes under unpleasantly hot conditions. I would further like to express my own deep gratitude and that of all others who are interested in the preservation of ancient monuments in Kenya to Mrs A. Selfe of Nakuru, whose untiring efforts to safeguard Hyrax Hill from despoliation since the excavations were completed, deserve widespread recognition.

The results obtained during the excavations, which covered a period of eighteen months, may be briefly summarised as follows:—

Site I.—Two occupational levels were revealed. (1) A Neolithic occupation site and contemporary cemetery (Mound D), containing 18 contracted interments which, in the case of females, were associated with flat stone bowls or platters; an obsidian industry, probably derived from the Upper Kenya Aurignacian, Phase B, and pottery which includes vessels of distinctive ovoid beaker form. The remains of this occupation were found to lie directly upon the 335-foot beach of Lake Nakuru, which, it has been shown, can probably be assigned to the recession of the Makalian lake.

(2) Overlying the Neolithic level described above, in an otherwise barren deposit of hillwash, were found some scattered fragments of stone basins, of the type known to belong to the Gumban B Variant of the Stone Bowl Culture. This Variant has been correlated by Leakey to the maximum period of the Nakuran Wet Phase (3).

(3) The final occupation of Site I, a settlement of stone-walled enclosures and associated burial pits. The cultural remains of this settlement include iron objects, glass beads, water-pipe bowls, cowrie shells and developed pottery resembling modern East African forms. The fact that coastal

trade appears to have been established, as evidenced by marine shells and the water-pipe bowls, which are generally believed to have been introduced by Arab traders to the East Coast of Africa, suggests that this settlement is of recent date, probably within historic or protohistoric times.

(For convenience sake this settlement is hereafter referred to as Iron Age. No analogies to the Iron Age of Europe are thereby implied, either on cultural or chronological grounds.)

Site II.—The north-east village. Excavation of two pit dwellings and partial excavation of a nearby midden revealed a culture distinct from the first and third at Site I, but connected with the Gumban B. Remains of domestic sheep and oxen were found and the pottery vessels recovered from the dwellings exhibit spouts and handles, together with impressed cord decoration, all of which characterise the Gumban B. The pits were found to have been dug into a deposit of coarse grey pumice, which is widely distributed in the Nakuru district and which is known to antedate the Makalian beaches. Stratigraphical evidence was lacking as to the date of this settlement relative to those at Site I, but a deposit of six to nine inches of humus, which was found to overlie both the midden and the infilling of the pits, suggests that it is not of such recent date as the Iron Age occupation, which is devoid of any overlying humus.

In addition to the excavations at Sites I and II, an isolated burial mound was dug, Mound E, which lay near to the main cemetery at Site I and was found to be contemporary.

Site I: Method of Excavation.

A series of six parallel cuttings 27 feet long (N.W.–S.E.) by 7 feet wide, with the exception of Cutting V, which was 8 feet wide, were dug through the Neolithic cemetery and occupation level. (See Plan I.) Cuttings I–V were subsequently extended 20 feet south-east, series Is–Vs. Cuttings VII, VIII, and IX were then excavated to include the north-east extension of the cemetery, Cuttings VII and VIII being parallel to the first series, but 21 feet long.

To the south-west of the first series, six further cuttings were dug, namely: Ia, Id, and Ie, 15 feet long and 10 feet wide, and Ix, Ib, Ic, 20 feet long and 10 feet wide. Cutting IIIb (10 by 10) and Cuttings IIc, IIIc, and IVc, 20 feet long and 10 feet wide, were then dug through the south-eastern and southern parts of the occupation site and cemetery. Cutting IIe and the northern extensions of Cuttings III and IV were then excavated in order to confirm the presumed limits of the cemetery structure in those areas. All these cuttings were excavated to the undisturbed subsoil and the entire burial structure was removed.

An extension of Cutting IIb, 30 feet long and 5 feet wide, was made in

a south-easterly direction, in order to ascertain whether a slight rise in the ground level, visible on the surface, was caused by an extension of the cemetery. It was, however, found to be due to an accumulation of debris derived from the adjacent Iron Age hut C.

Reference to Plan I and to Sections K–K′ and L–L′ will show that in Cuttings Ia, Id, Ix, Ib, and Ic the stone walls of the Iron Age enclosures and hut circles were superimposed on the hillwash which overlay the cemetery structure. Nine intrusive burial pits were also found, concentrated mainly in Cuttings III and IV.

In addition to the cuttings mentioned above, a further series of eight was excavated in the Iron Age enclosure C (If–In). This area yielded the greatest number of iron objects, pot sherds and beads. Finally, the Iron Age huts A and C were excavated and two trial cuttings made in Enclosure B and north of Hut A, these yielded little result.

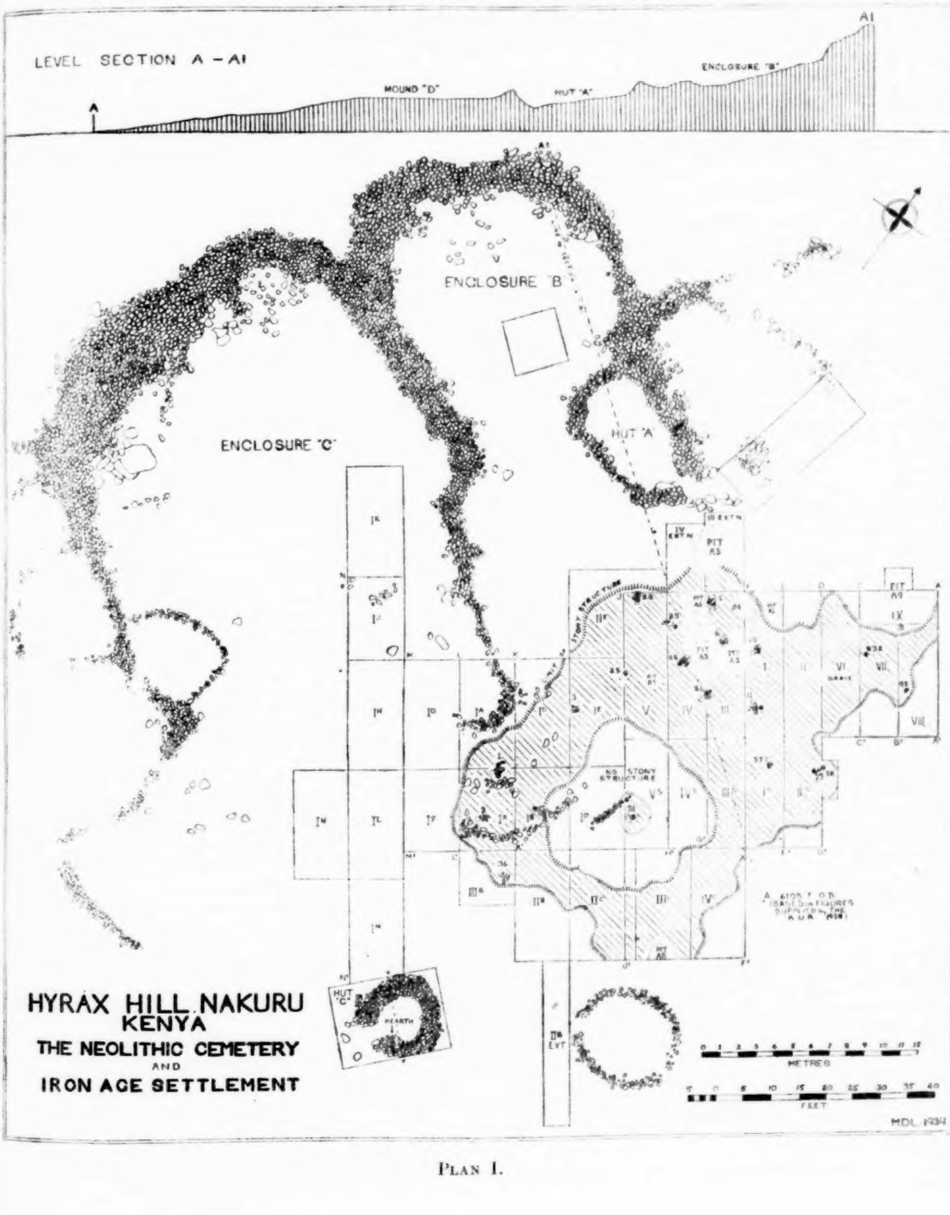
Riddles with 1/8 inch mesh were used throughout the greater part of the excavations.

Site I: The Neolithic Occupation Site and the Cemetery.

The discovery of this occupation level and associated interments took place accidentally during the excavations carried out in the Iron Age midden which lay at the entrance of Enclosure C. No trace of the extensive stony structure which was subsequently found to cover the Neolithic interments was visible prior to excavation, since it was entirely masked by the accumulation of hillwash, humus, and living site debris from the Iron Age settlement. A certain number of obsidian implements to be seen on the surface of the ground did, however, indicate that an earlier occupation might possibly exist on the site and that these had been brought to the surface by rodent action.

The cultural remains of the Neolithic occupation, consisting of implements and waste flakes, potsherds, pestles, stone platter fragments, and broken animal bones and teeth were derived from an almost stoneless stratum of brown loamy soil which averaged 1 foot in thickness and covered a considerable area. This stratum lay upon the waterworn stones and sandy gravel of the 335-foot beach in the central part of the excavated area and was usually found at a depth of 1½ to 3 feet from the present ground surface. In addition to the cultural objects contained in this level, a number of artefacts in an unrolled condition were recovered from among the beach pebbles which are typologically indistinguishable from those occurring in the overlying occupation layer.

The occupation level was immediately overlain in certain areas by the stony structure of some nineteen burials. These must unquestionably be associated with the living site on account of the lack of intervening strata



PLAN I.

Mary D. Leakey. *Neill & Co., Ltd.*

HYRAX HILL NAKURU KENYA
SITE I
NORTH-WEST—SOUTH-EAST SECTIONS
THROUGH MOUND 'D'
IRON AGE BURIAL PITS & MIDDEN
FEET
METRES
IRON AGE HEARTH
BOULDERS INCORPORATED IN THE BEACH
SYMBOLS:
TOP SOIL
MIDDEN (ASHY)
HEARTHS
IRON AGE
HILLWASH (LAYER 1)
BROWN SOIL (OCCUPATION LEVEL) (LAYER 2)
335' BEACH. (LAYER 3)
NEOLITHIC
NOTE
POSITIONS OF HUMAN REMAINS DIAGRAMATIC

PLAN II.

between the occupation level and the burials, and also because the stone platters and pestles recovered as grave goods are entirely similar to those found in the occupation level. In fact, there seems little doubt that the cemetery formed the burial ground of the people who lived at the site.*

It may be mentioned that the occurrence of interments on an Upper Palaeolithic living site is recorded at Gamble's Cave, in Phase B of the Upper Kenya Aurignacian and is also known in the Kenya Neolithic, particularly in the Gumban A Variant of the Stone Bowl Culture. This variant, although not identical, is closely comparable to that found at Hyrax Hill.

The Occupation Level.

The occupation level, which is referred to in Sections, etc. as layer 2, rested in part, as has been mentioned, on the 335-foot beach. In the northern part of the excavated area, however, the occupation level continued beyond the highest point of the beach and was found to lie upon the stony scree derived from the hill. This region yielded noticeably fewer remains than any other. In the central area, where the occupation level overlay the beach material, it was noticed during excavation that the waterworn stones and pebbles frequently presented the appearance of having been levelled, to form, as it were, a roughly cobbled floor to the living site. It seems probable that the occurrence of a number of unrolled implements in the beach material may be due to the fact that the disturbance of the beach took place after the site was already in occupation, when it would follow that a proportion of the artefacts lying on the surface of the ground would become incorporated during the levelling process.

In the south and south-western regions of the excavated area the occupation level was found to lie upon a thin layer of sand, containing particles of pumice derived from the pumice subsoil which is widely distributed in the Nakuru district. This is believed to have been deposited during the final major eruption of the nearby volcano, Menengai, now extinct.

Cultural remains were noticeably more plentiful in this last area, which comprised Cuttings Ib, IIb, Ic–IVc, and IIIc–Vs. The fact that no traces of hearths could be discovered and that animal bones, although present, were relatively scarce seems remarkable in view of the large numbers of implements and of potsherds which were found. The concentration of either pottery or of certain tool types such as scrapers or burins within restricted areas was very marked. This phenomenon appears to be fairly

* The custom of burying on the living site is still prevalent among certain modern E. African tribes who consider it essential for a man to be buried beneath the floor of his hut, the relatives continuing to occupy the hut after the interment has taken place.

common in prehistoric living sites and was particularly noticeable in the Aurignacian levels at Gamble's Cave. It may, perhaps, indicate that specialisation in certain crafts was already in existence.

The accumulation of living site debris in the excavated area, which a series of fourteen trial pits further proved to extend some two or three hundred feet in a southerly direction, argues for an occupation covering a considerable period of time. If this was the case, it seems strange that as stone was so conveniently situated at the site and was extensively used for the cemetery, none was employed in construction of dwellings. On the evidence obtained from excavation, however, it appears that if any huts or shelters existed, they were built of perishable materials which have left no trace, although it is always possible that a certain amount of stone may have been used for the purpose and that it was subsequently removed and placed on the burials. This explanation does not seem likely, in view of the almost total absence of stones in layer 2.

I. The Industry.

Material.—The material from which the industry was manufactured proved to be almost exclusively obsidian, a natural volcanic glass. Some half-dozen flakes of chalcedony were found, together with a very few of basalt and rhyolite. These, however, form but a negligible proportion of the whole assemblage.

Four distinct types of obsidian were in use, two of which have not up to the present been identified with any known source of supply. These two obsidians, grey and brown in colour respectively, are both translucent. They are not so common, however, as an opaque black obsidian which shows a bottle-green tinge in thin section. This, on superficial examination, bears a close resemblance to the fourth type and is only distinguishable from it [apart from microscopic examination] by the fact that the latter has a somewhat grey tinge and small black specks when seen in thin section.

Specimens of the last two varieties from the site were submitted to Mr. P. M. Game of the Department of Mineralogy, British Museum, together with samples of the obsidian from Mt. Eburu and the Njorowa Gorge prehistoric obsidian mines near Lake Naivasha. He very kindly carried out a detailed examination on specific gravity and refractive index and his report is appended on p. 406. Meanwhile, his conclusions may be briefly summarised as follows. The bottle-green obsidian from Hyrax Hill, which bore a superficial resemblance to the raw material from Eburu, does in fact belong to the same group, known as trachyte obsidians, and is also a fairly close match from a petrological point of view. Likewise, material obtained

from the mines in the Njorowa Gorge proved analogous in physical properties to the second sample from Hyrax Hill and to belong to the rhyolite obsidians.

In view of the correspondence between the two specimens, which are, in addition, easily distinguishable from one another, it seems permissible to assume that a considerable proportion of the material in use at Hyrax Hill was derived from Mt. Eburu and the Njorowa Gorge mines, which lie in the Rift Valley some 30 or 40 miles south of the site. No prehistoric obsidian mines have so far been discovered on Mt. Eburu comparable to those at Naivasha, which number fifteen or more separate galleries cut into a horizontal seam of obsidian. The Eburu obsidian is, however, very plentiful and so accessible that it has been used for commercial purposes during recent years.

General Characteristics of the Industry.

The fact that raw materials had to be obtained from considerable distances may in part account for the small size of the implements. Nevertheless, the high proportion of microlithic crescents and the occurrence of micro-burins necessitate the term Microlithic being applied to the industry as a whole. It must not be overlooked, however, that a number of scrapers, burins, etc. are found in association with the microlithic forms, which are of a size only slightly below the average for such implements in the Upper Palaeolithic cultures of Kenya.

Crescents are the most common implement in the assemblage, which also includes micro-burins, burins, scrapers, borers (very rare), obliquely trimmed points, non-crescentic backed blades, lames écaillées, untrimmed blades (very rare), sinew frayers, utilised flakes of the type sometimes described as triangular fabricators, together with cores and sundry flakes showing utilisation. The waste material recovered amounts to 16,056 whole and bulb ends of flakes and 27,499 distal fragments.

The percentages of the various implements and by-products in the industry, excluding waste material, are as follows:—

Crescents	27·93 per cent.	Backed blades	2·43 per cent.
Borers	0·57 ,,	Lames écaillées	1·32 ,,
Obliquely trimmed points	0·52 ,,	Untrimmed blades	0·27 ,,
Micro-burins	2·72 ,,	Sinew frayers	·73 ,,
Burins	5·52 ,,	Utilised flakes (triangular)	7·05 ,,
Burin spalls	5·63 ,,	Utilised flakes, sundry	30·93 ,,
Scrapers	5·3	Cores	8·5 ,,
Hollow scrapers	0·52 ,,		

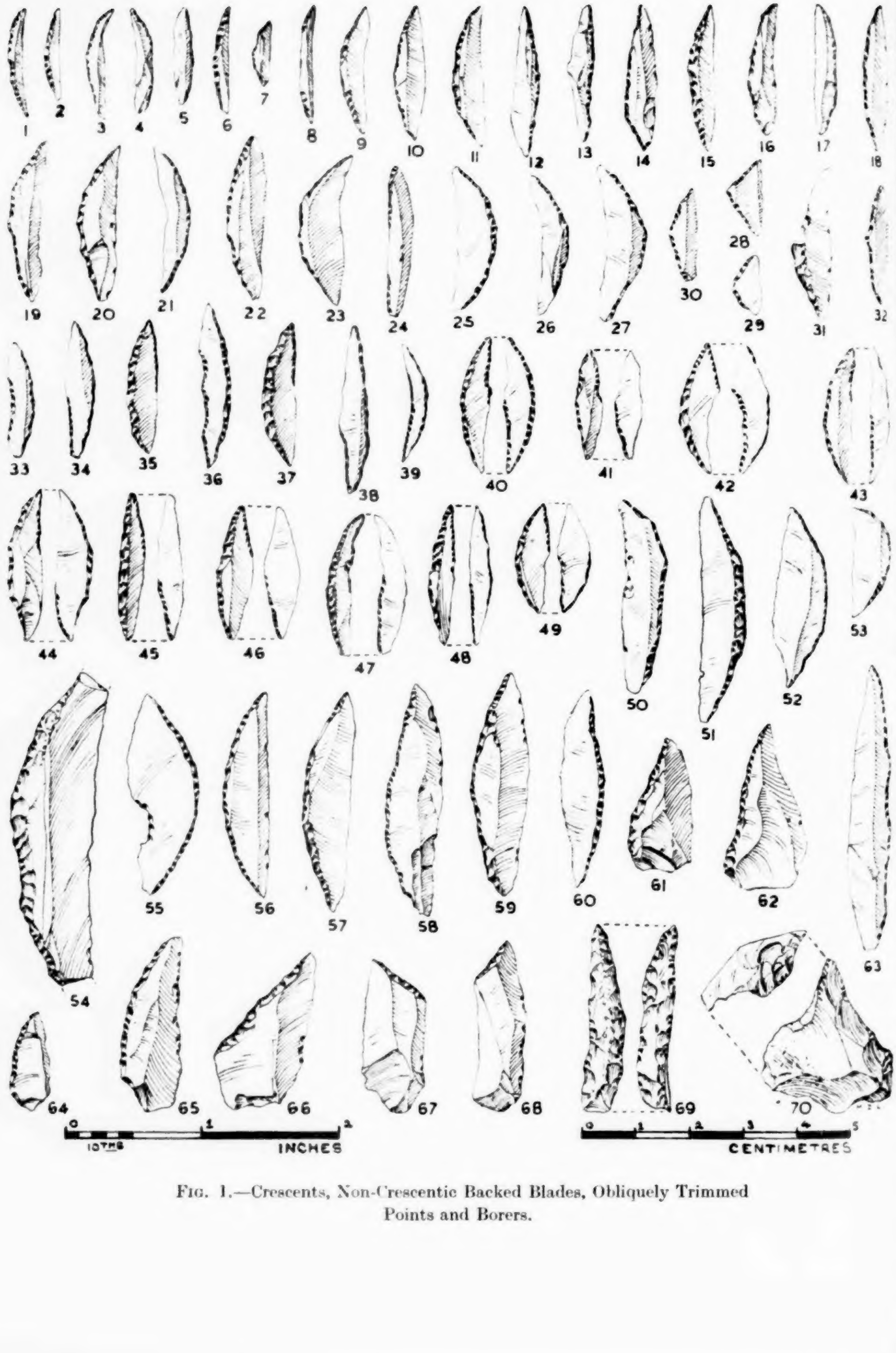


FIG. 1.—Crescents, Non-Crescentic Backed Blades, Obliquely Trimmed Points and Borers.

(1) *The Crescents.*

Some 593 undamaged specimens were recovered from layers 2 and 3. These include examples ranging in length up to 52 millimetres, but specimens under 30 mm. predominate, amounting to 489. In addition to the undamaged crescents, 2015 fragments were recovered. In 657 of these over 50 per cent. of the implement is preserved, with the result that some 1247 complete specimens are represented in the series, although only those which are undamaged will be described.

The larger crescents have sometimes been described as backed blades, but in the present paper the term is confined to implements of the Châtelperron type, in which the bulbar extremity is retained. A subdivision of the Hyrax Hill crescents into "lunates" and "backed blades" does not seem justified on account of the very gradual variation in size and similarity in form throughout the series.

A characteristic feature of both the large and small crescents is that the tips or points are of equal thinness, the bulbar extremity of the original flake having been entirely removed. In general form, the implements are long

Simple Crescents: (1) C. IIIc, L/2, 0·3751 *; (2) C. Vs, L/2, 0·6715; (3) C. IIc, L/2, 0·1501; (4) C. Ib, L/2, 0·311; (5) C. IIIc, L/2, 0·3752; (6) C. IIb, L/3, 0·4881; (7) C. IIc, L/2, 0·1179; (8) C. If, L/3, 0·2484; (9) C. Ib, L/2, 0·295; (10) C. IIIb, L/3, 0·5603; (11) C. IIIb, L/2, 0·5462; (12) C. II, L/2, 0·1711; (13) C. Ib, L/2, 0·297; (14) C. IIIc, L/2, 0·3762; (15) C. IIc, L/2, 0·1499; (16) C. IIc, L/2, 0·1159; (17) C. IVc, L/2, 0·2971; (18) C. IIc, L/2, 0·1075; (19) C. IIc, L/3, 0·1689; (20) C. IIIb, L/2, 0·5513; (21) C. IVs, L/2, 0·6422; (22) C. IIc, L/2, 0·1071; (23) C. IIc, L/2, 0·1061; (24) C. III, L/2, 0·1780; (25) C. IIIb, L/2, 0·5467; (26) C. IIIb, L/2, 0·5461; (27) C. Ig, L/2, 0·2530.

Triangles: (28) C. Ic, L/2, 0·2131; (29) C. VII, L/2, 0·5956.

Shouldered Crescents: (30) C. IIb, Ext. L/2, 0·5046; (31) C. IIIc, L/2, 0·3748; (32) C. If, L/2, 0·2437.

"Bevelled-edge" or Borer Crescents, Retouched from one Direction: (33) C. V, L/2, 0·1963; (34) C. Ic, L/2, 0·790; (35) C. IIc, L/2, 0·1495; (36) C. IIc, L/2, 0·5715; (37) C. IVs, L/2, 0·6423; (38) C. IVs, L/2, 0·6426; (39) C. IIb, L/2, 0·4575.

"Bevelled-edge" Crescents, Retouched from two Directions: (40) C. Ix, L/2, 0·893; (41) C. IIIs, L/3, 0·6273; (42) C. IIIc, L/2, 0·3750; (43) C. IIIc, L/2, 0·5714; (44) C. IIc, L/2, 0·1078; (45) C. IVc, L/2, 0·2945; (46) C. Ic, L/2, 0·2290; (47) C. IIc, L/2, 0·5705; (48) C. IIIc, L/2, 0·3745; (49) C. IIc, L/2, 0·5703.

Large Crescents: (50) C. IIb, Ext. L/2, 0·5235; (51) C. IIIc, L/2, 0·3667; (52) C. Ib, L/2, 0·310; (53) C. Ib, L/2, 0·305; (54) Crescentic backed blade discovered with Skeleton No. 21, C. IV, 0·963; (55) C. IVc, L/2, 0·2858; (56) C. IIb, L/3, 0·4872; (57) C. IVc, L/3, 0·4322; (58) C. IIIs, L/3, 0·6269; (59) C. Is, L/2, 0·7055; (60) C. IVc, L/2, 0·2865.

Non-crescentic Backed Blades: (61) C. IIb, L/2, 0·4490; (62) C. Ib, L/2, 0·292; (63) C. III, Ext. X. L/3, 0·1688; (64) C. IIs, L/2, 0·7251; (65) C. IIIs, L/2, 0·6149.

Obliquely Trimmed Points: (66) C. Ic, L/2, 0·2289; (67) C. IIIc, L/2, 0·4119; 0·4889; (68) C. IIIs, L/2, 0·6047.

Borers: (69) C. IIs, L/2, 0·7203; (70) Borer with reverse retouch, C. IIIs, L/2, 0·6046.

* Field catalogue numbers.

and narrow and, with the exception of 21 examples, dorsal ridges are present.

In view of the equality in size of both ends and the occurrence of microburins in association with the crescents, it is probable that the method of manufacture suggested by M. Siret was largely employed (4).

Although the majority of the crescents are long and narrow, there are a few examples which are broad and relatively short. The regularity of the trimming or blunting on the backs of the implements varies considerably, although it invariably extends the whole length of the crescent.

108 examples of a specialised form of crescent were found. These in every case exhibit a deliberate trimming of the cutting edge. The retouch is very fine and gives the appearance of bevelling. A few shouldered and subtriangular forms also occur.

The range in length and breadth for the series of 593 complete specimens is as follows:—

Length:

10–20 millimetres	164 specimens	average maximum breadth 6·5 mm.	
20–30 ,,	325 ,,		
30–40 ,,	96 ,,	average maximum breadth 8·7 mm.	
40–52 ,,	8 ,,		

Signs of utilisation are present on 42 of those which exceed 30 mm. in length; on 94 of those under 30 mm., and on 759 fragments.

"*Bevelled-edge*" *Crescents*.—As mentioned above, 108 examples of this type of crescent were recovered, together with 158 fragments. The series ranges in length from 12 to 30 mm., with an average of 22·2 mm. The average breadth is 5·5 mm. Although essentially of the same general form as the crescents previously described, the distinguishing feature in this series is the presence of fine retouch along the lateral edge opposed to the blunted back (fig. 1, Nos. 33–47). In 36 examples this retouch is carried out from one direction only, either from the upper or from the obverse face of the implement. More commonly, however (72 examples), a reversed retouch is present, the lateral edge at one extremity being trimmed from the upper or lower face and the other extremity from the opposite direction. This trimming does not overlap and the point of contact sometimes forms a slight shoulder on the cutting edge (fig. 1, Nos. 40–42).

In those specimens which are trimmed from one direction only, the bevelling is not found on the entire length of the cutting edge, but is confined to one extremity only and extends little more than half the length of the implement. Some half-dozen specimens were also found in which the bevelling occurs only in the central part of the cutting edge and does not extend to either end (fig. 1, No. 33).

It is impossible to regard the bevelling on the cutting edges of these crescents as other than intentional on account of the number recovered and the regularity of the retouch which precludes the possibility that it might be due to utilisation. It is possible that those specimens in which either one or both extremities are trimmed may have been used as boring tools.

Shouldered Crescents and Triangles.—Some 17 complete and 6 fragments were found which show a marked projection or shoulder on the blunted back, together with three triangles (fig. 1, Nos. 30–32 and 28–29). Five of these show utilisation, and the average length for the 17 specimens is 19·6 mm. The average maximum breadth is 5·1 mm. Apart from the dorsal projection these crescents are comparable to the common form and, in view of the small number recovered, they must be regarded as atypical. The three triangles are crudely made and probably represent merely a variation of the shouldered crescents.

Mention must also be made of 4 fragments of large crescents which greatly exceed in size any of those described above. Since these are merely fragments no length measurements are possible, but an average width of 13 mm. is represented, with a corresponding thickness. Three of these fragments are slightly abraded and may have been present in the beach before the construction of the cemetery. The large crescent discovered in the grave of Skeleton No. 21 (fig. 1, No. 54) may also be intrusive on account of the difference in technique.

(2) *Borers, Obliquely Trimmed Points and Backed Blades* (*Non-crescentic*).

Borers (fig. 1, Nos. 69 and 70).—22 examples. Average length of the complete specimens 21 mm., ranging from 15 to 36 mm. In eight specimens the borer point is formed by reversed retouch—that is, one side of the point has been trimmed from the upper face and the opposite side from the lower face of the implements. The tools cannot be said to conform to any one type in view of the difference in size within the small series and in the technique of the trimming, which varies from a steep to a small, nibbling retouch. In a few examples the points are slightly curved, but the more usual form is straight.

Obliquely Trimmed Points (fig. 1, Nos. 66, 67, 68).—23 complete examples and 5 fragmentary. Average length of the complete specimens 28·7 mm., ranging from 17 to 35 mm. The trimming on the lateral edges of these implements, which are straight and not curved as in the backed blades, is confined to the area near the point and never extends the entire length. In most cases signs of utilisation are present on the lateral edge opposed to the trimming (which varies in length from 8 to 26 mm.); in view of this utilisation and of the fact that the tools, though few in number, follow a definite

type, it would seem that they should be regarded as finished products and not stages in the manufacture of crescents or backed blades.

Backed Blades (fig. 1, Nos. 61 to 65).—108 complete examples and 126 fragments. Average length of the complete specimens 24 mm., ranging from 18 to 33 mm. In this series are 34 specimens which may be described as *Châtelperron* forms. The bulb end of the original flake is retained and the trimming or "backing" which is on one lateral edge curves round to form a point at the distal extremity. A further 29 specimens were found in which the distal extremities of the flakes form the butt ends of the implements.

The remainder of the series is composed of unfinished specimens, some of which probably represent unfinished crescents in addition to unfinished backed blades.

The backed blade series is for the most part asymmetrical and crudely made, in no way comparable to the crescents.

(3) *The Micro-Burins.*

A total of 229 micro-burins was recovered. 87 of these are on the bulbar ends of flakes and 142 are on distal extremities; in the latter, the butt end of the micro-burin is formed by the extremity of the original flake. Of the 87 specimens on bulb ends, 56 show the burin scar on the right side and 31 on the left, always directed from the thick, notched edge towards the thin edge. The 142 examples on extremities of flakes show the burin scar on the right side in 82 cases and on the left in 60.

The series ranges in length from 6 to 36 mm. as follows:—

Bulb end specimens—	6–15 mm.,	53 examples.
,, ,, ,,	15–36 mm.,	33 ,,
Distal end specimens—	9–15 mm.,	89 ,,
,, ,, ,,	15–36 mm.,	54 ,,

The specimens ranging in length from 6–15 mm. form 63·8 per cent. of the total and those from 15–36 mm. 36·2 per cent. It should be mentioned that positive "burin" flake scars are shown on 38 bulb end specimens and on 91 distal, while negative scars occur on 47 of the former and on 54 of the latter.

No traces of utilisation are to be seen on any of the specimens, and it would seem that at Hyrax Hill the micro-burins should be regarded merely as by-products of a specialised form of crescent manufacture.

An additional 50 specimens were found which appear to be mis-hits or aberrant forms of the micro-burin rather than fragmentary backed blades, crescents or borers broken during use. Nine of these are illustrated in fig. 2, Nos. 21–29. It will be seen that a trimmed notch is invariably present,

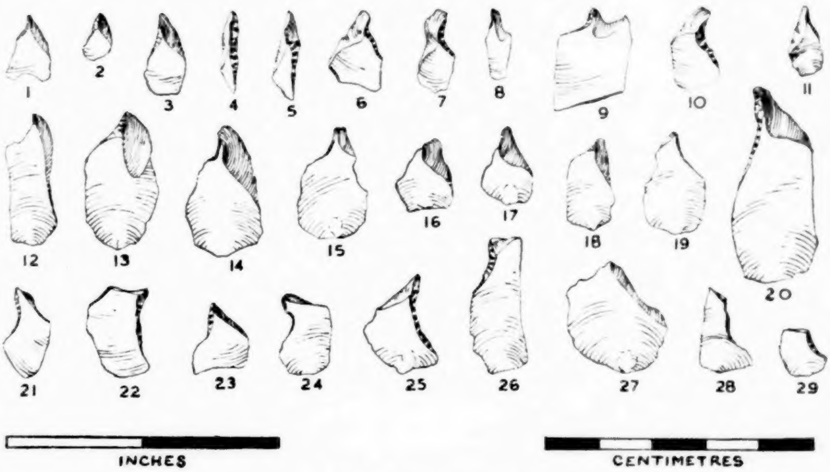


FIG. 2.—Micro-Burins.

(1) C. IIs, L/2, 0·7166; (2, 3) C. IIIc, L/2, 0·4044, 4017; (4) C. IIc, L/2, 0·1040; (5, 6) C. IIb, L/2, 0·4484, 4475; (7) C. III, L/2, 0·4040; (8) C. IIIs, L/2, 0·6257; (9) C. IIb, L/2, 0·4478; (10) C. IVc, L/2, 0·3263; (11) C. Is, L/2, 0·7039; (12) Cs. IIc–IIIc, L/2, 0·5688; (13) C. Ic, L/2, 0·2132; (14) C. IIb, L/2, 0·4472; (15) C. IIIc, L/2, 0·4000; (16) C. IVs, L/2, 0·6360; (17) C. IIIs, L/2, 0·6253; (18) C. IVc, L/2, 0·3270; (19) C. Ib, L/2, 0·405; (20) C. IVc, L/2, 0·3262.

Mishits.—(21) C. IIIc, L/2, 0·4001; (22) C. IIc–IIIc, L/2, 0·5756; (23) C. IIc, L/2, 0·1045; (24) C. IVs, L/2, 0·6361; (25) C. If, L/2, 0·2407; (26) C. IVc, L/2, 0·3269; (27) C. IIIc, L/2, 0·4011; (28) C. IIc, L/2, 0·1385; (29) C. IIIc, L/2, 0·4038.

truncated by a straight, or more often oblique, transverse fracture which is quite distinct from the characteristic micro-burin flake scar.

(4) *Burins.*

The total number of these tools recovered amounts to 246. Angle burins predominate, of which a large proportion are made on bulb ends of flakes, the striking platform of the original flake being partly or wholly trimmed to form the transverse edge of the implement. Among the specimens made on distal extremities of flakes, a large number are broken short of the bulbar end; these frequently show utilisation on the fractured surface and it is probable, in view of the difficulty of obtaining obsidian at the site, that broken flakes were expressly chosen for the manufacture of burins.

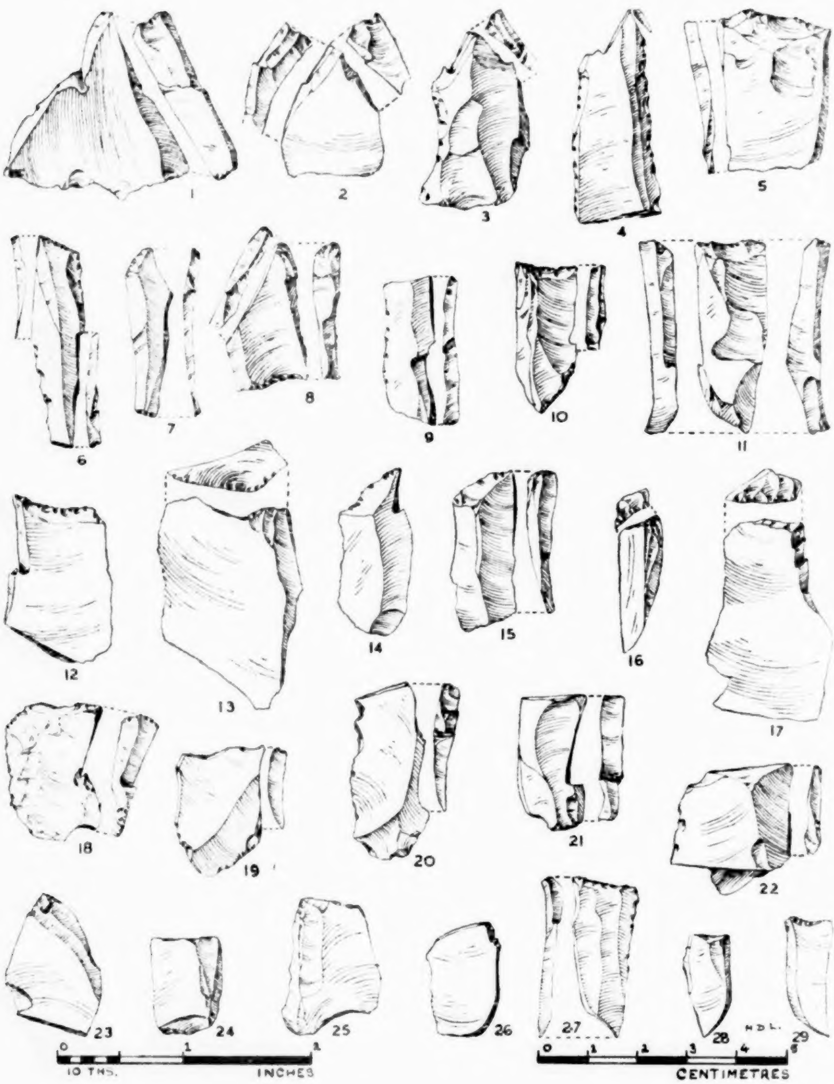

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Fig. 3.—Burins.

Nine categories of burins may be distinguished, as follows:—

(1) "*Bec-de-flute.*"
(2) Double-ended angle.
(3) Double angle (on same end).
(4) Notched or concave angle.
(5) Oblique angle.
(6) Straight angle.
(7) Angle on broken edges (simple).
(8) "*Burins plans.*"
(9) "Recurving" angle.

(1) "*Bec-de-flute*" *Burins* (fig. 3, Nos. 1–4).—18 examples. Average length 27·4 mm., ranging from 18 to 41 mm. (Owing to the impossibility of determining whether the implements have been broken before or after manufacture, every specimen has been measured with the exception of those in which a burin spall is truncated by the fracture.)

Included in this category are simple "*bec-de-flute*" burins (8 examples) having in all two blows, one on either side of the chisel edge, and also burins formed by the removal of multiple spalls from one or both sides. The edge in all specimens is, however, always straight and not curved as in the polyhedric burin. It should be mentioned that there is only one example on a flake which retains the bulbar end.

(2) *Double-ended Angle Burins* (fig. 3, Nos. 5–9).—14 examples. Average length 27·4 mm., ranging from 26 to 43 mm. In this small series are: combined double-ended straight angle, double-ended oblique, straight and oblique angle burins at either end of the implements.

(3) *Double-angle Burins* (fig. 3, Nos. 10 and 11).—16 examples. Average length 27·5 mm., ranging from 23 to 39 mm. Eight specimens in the series have the double burin on the bulbar end of the original flake, the bulb itself being trimmed away and a transverse notch formed. Both single- and multiple-blow burins are represented. The remainder of the series are

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"*Bec-de-flute*" *Burins*: (1) C. Vs, L/2, 0·6601; (2) C. IVc, L/2, 0·2844; (3) C. Id, L/2, 0·731; (4) C. IIb. L/2, 0·4470.

Double-ended Angle Burins: (5) C. IIIc, L/2, 0·3631; (6) C. IIIc, L/2, 0·3644; (7) C. IIIc, L/2, 0·3652; (8) C. Id, L/2, 0·693; (9) C. IIc, L/2, 0·1019.

Double-angle Burins (on same end): (10) C. Ic, L/2, 0·506; (11) C. Ib, L/2, 0·222.

Notched or Concave Angle Burins: (12) C. IIc, L/2, 0·1004; (13) C. IIIc, L/2, 0·3627.

Oblique Angle Burins: (14) C. IIIc, L/2, 0·3648; (15) C. IIc, L/2, 0·1462; (16) C. IIc, L/2, 0·1463.

Straight Angle Burins: (17) C. IIb, Ext. L/2, 0·4963; (18) C. IIIc, L/2, 0·3629; (19) C. IVc, L/2, 0·2843.

Angle Burins on Broken Edges (Simple): (20) C. IIb, L/2, 0·4464; (21) C. IVc, L/2, 0·2840; (22) C. V, L/2, 0·1959.

"*Burins Plans*": (23) C. IIb, L/2, 0·4457; (24) C. IIc, L/2, 0·998; (25) C. IIb, L/2, 0·4458.

"*Recurring*" *Angle Burins*: (26) C. IIIc, L/2, 0·4071; (27) C. IIIb, L/2, 0·5424; (28) C. IIc, L/2, 0·1014; (29) C. IIc, L/2, 0·1464.

straight angle burins, the notch being replaced by a straight trimmed transverse edge.

The series of single-ended angle burins is subdivided into the four above categories for convenience, yet there is a gradation between the notched, straight, and oblique varieties which renders the subdivision somewhat arbitrary. The last category of burins on broken edges is, however, quite distinct.

(4) *Notched or Concave Angle Burins* (fig. 3, Nos. 12 and 13).—17 examples. Average length 27·5 mm., ranging from 14 to 40 mm. In this series specimens made on bulb ends of flakes predominate. All are characterised by a notch, trimmed from the obverse faces of the implements. The burin spalls are both single and multiple.

(5) *Oblique Angle Burins* (fig. 3, Nos. 14, 15, and 16).—57 examples. Average length 30·1 mm., ranging from 15 to 61 mm. The angle between the burin spalls and the trimming which forms the opposed lateral edge of the implements varies from 45° to 75°. Any specimen in which this angle exceeds 75° has been described as a straight angle burin. There is also a considerable range in the length of the trimmed edge, from 5 to 26 mm., in accordance with the size of the implement as a whole.

(6) *Straight Angle Burins* (fig. 3, Nos. 17, 18, and 19).—31 examples. Average length 28·2 mm., ranging from 20 to 46 mm. Single-blow burins, although scarce, do occur in this group. All are characterised by a trimmed, straight, or slightly curved transverse edge, lying approximately at right angles to the burin facets.

(7) *Angle Burins on Broken Edges (Simple)* (fig. 3, Nos. 20, 21, and 22).—28 examples. Average length 25·4 mm., ranging from 21 to 38 mm. The series is characterised by the absence of trimming on the transverse edge, which is usually a plain, but is sometimes a hinged fracture.

(8) "*Burins Plans*" (fig. 3, Nos. 22, 23, and 24).—23 examples. Average length 27·4 mm., ranging from 20 to 38 mm. In four specimens the direction of the burin facets lies oblique to the length of the implement, in the remainder it is parallel. All the specimens show the characteristic curving over of the burin facets on to the obverse face.

(9) "*Recurving*" *Angle Burins* (fig. 3, Nos. 26, 27, 28, 29).—25 examples. Average length 23·7 mm., ranging from 15 to 34 mm. Although the working ends of the implements in this category fall under three of the foregoing headings, namely notched, oblique, and straight angle burins, a distinguishing feature common to the group is that one of the lateral burin spalls has, in every case, been struck with sufficient force to cause it to continue down one lateral edge, recurve across the width of the flake and terminate on the opposite lateral edge from that on which it was struck. The result is the truncation of the implements by the burin spall, part of which forms the

butt. Secondary burin flake scars are frequently present on these primary spalls.

The percentages of the above types, relative to the total number of burins recovered, is as follows:—

(1) "*Bec-de-flute*" burins	8·8 per cent.	
(2) Double-ended angle	5·6	,,
(3) Double angle	6·7	,,
(4) Angle, notched, oblique, straight and simple	54·8 per cent.	
(8) "*Burins Plans*"	9·3	,,
(9) "Recurving" angle	10·3	,,
Broken	4·5	,,

251 burin spalls or facets were recovered. These call for no particular comment with the exception of 22 specimens which are apparently derived from the recurving angle burins. In a number of cases these show the remains of a truncated angle burin at the distal extremity of the spall.

(5) *Scrapers.*

A total of 236 scrapers was recovered, excluding hollow scrapers which will be described separately. The complete specimens amount to 99, whilst 23 are unfinished or heavily damaged in use. All the broken examples show a transverse fracture, with the exception of 10 in which the break is longitudinal.

The following types may be distinguished:—

(1) End scrapers.
(2) Discoidal scrapers.
(3) Double-ended scrapers.
(4) Burin scrapers.
(5) Square-ended scrapers on narrow blades.

(1) *End Scrapers* (fig. 4, Nos. 1 to 12).—77 examples. Average length 28 mm., ranging from 12 to 41 mm. These include broad short specimens with correspondingly wide scraping edges, elongate forms in which the lateral edges of the implements are roughly parallel, approaching the duck-bill type, and lastly, elongate specimens in which the lateral edges converge at the butt end. With four exceptions, all the examples are round-ended.

(2) *Discoidal Scrapers* (fig. 4, Nos. 13 and 14).—7 examples. Average maximum diameter 31 mm., ranging from 26 to 33 mm. This relatively scarce type is characterised by the presence of retouch on more than two-thirds of the circumference, the bulb of the original flake generally having been trimmed away.

(3) *Burin Scrapers* (fig. 4, No. 17).—6 examples. Average length 27 mm., ranging from 19 to 30 mm. With the exception of one *bec-de-flute*,

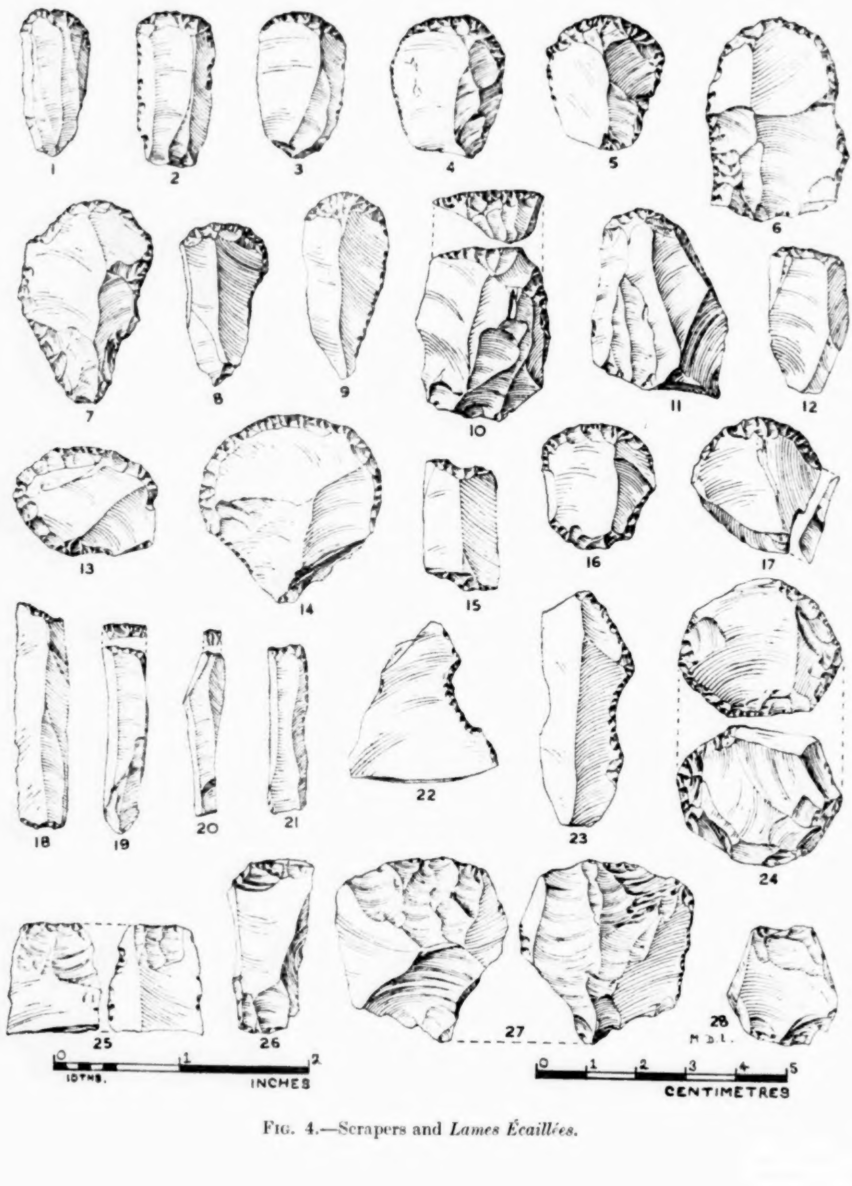

FIG. 4.—Scrapers and *Lames Écaillées*.

the burins which are present on the butt ends of these implements are angle burins of the usual types.

(4) *Double-ended Scrapers* (fig. 4, Nos. 15 and 16).—5 examples. Average length 26·1 mm., ranging from 24 to 29 mm. This series includes examples which combine round-ended and hollow scrapers, double square-ended and double round-ended specimens.

(5) *Square-ended Scrapers on Blades.* (fig. 4, Nos. 18–21).—19 examples. Average length 35·5 mm., ranging from 22 to 44 mm. The implements in this series are invariably made on long, narrow flakes, and the scraping edge, which is necessarily narrow, is either oblique or straight. The average width for this edge is 7·9 mm.

The percentages of the types to the total number of scrapers recovered is as follows:—

End scrapers	32·4 per cent.
Discoidal scrapers	3·3 ,,
Burin scrapers	2·4 ,,
Double-ended scrapers	2·4 ,,
Square-ended, on blades . . .	7·5 ,,
Broken and unfinished	51·0 ,,

(6) *Hollow Scrapers* (fig. 4, Nos. 22, 23).

Hollow scrapers are relatively scarce, only 23 examples having been recovered. The trimming of the notches, which are situated haphazard on a flake or broken piece of obsidian, varies from fine, shallow retouch to crude step-flaking. The average length of the notches is 13 mm., ranging from 8–23 mm.

End Scrapers: (1) C. IVc, L/2, 0·2800; (2) C. IIIc, L/2, 0·3558; (3) C. IV, L/2, 0·964; (4) C. Ib, L/2, 0·209; (5) C. IIIs, L/3, 0·6279; (6) C. Ie, L/2, 0·2282; (7) C. IIIs, L/2, 0·6095; (8) C. Vs, L/2, 0·6642; (9) C. IVs, L/3, 0·6540; (10) C. IIb, L/2, 0·4430; (11) C. Vs, L/2, 0·6647; (12) C. III, L/2, 0·1778.

Discoidal Scrapers: (13) C. Ib, L/2, 0·210; (14) C. IVs, L/2, 0·6354.

Double-ended Scrapers: (15) oblique ended, C. Id, L/2, 0·729; (16) round ended, C. III, L/2, 0·1777.

Scraper-burin: (17) C. IIIs, L/2, 0·6100.

Square or Oblique-ended Scrapers on Narrow Blades: (18) C. IIc, L/2, 0·1453; (19) C. Ic, L/2, 0·498; (20) C. IIc, L/2, 0·1451; (21) C. IIc, L/2, 0·1452.

Hollow Scrapers: (22) C. IIIs, L/2, 0·6044; (23) C. IIb, L/2, 0·4444.

"*Lames Écaillées*": (24) Scaled flaking is present on both faces and on the greater part of the circumference—C. Id, L/2, 0·724. (25) Scaled flaking is present on both faces of the implement, but is confined to one extremity—C. Vs, L/2, 0·6658. (26) Double-ended specimen showing scaling on one face—C. IIIs, L/2, 0·6090. (27) Heavily utilised double-ended specimen showing scaling on both faces—C. Ie, L/2, 0·2267. (28) Double-ended specimen showing slight scaling on the obverse face in addition to that shown—C. III, L/2, 0·1174.

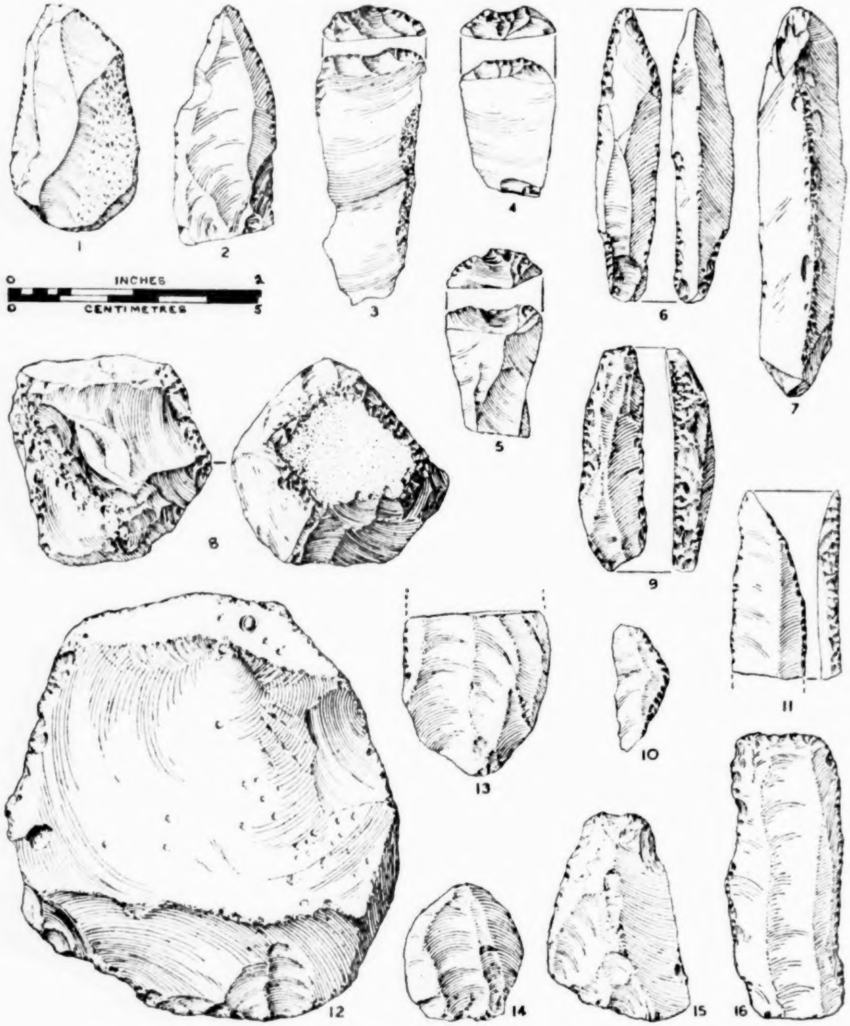

FIG. 5.—Blades, "Sinew Frayers," Flakes showing Battered Utilisation, Hammer-stone and Rolled Implements and Flake from the 335-foot Beach.

Blades: (1) C. Ib, L/2, 0·235; (2) C. Ie, L/2, 0·2288.

"*Sinew Frayers*": (3) C. IIb, L/2, 0·4960; (4) C. Is, L/2, 0·7022; (5) C. IIc, L/2, 0·997.

(7) *Lames Écaillées* (fig. 4, Nos. 24 to 28).

59 examples. Average length 28·7 mm. ranging from 7 to 36 mm. 28 examples show the typical "scaled" flaking on opposite edges, 23 on one edge only, and 5 on two edges lying at right angles to one another. The remainder are broken and indeterminate. The majority of the implements show scaling on both faces, a few examples occur, however, in which the scaling is present on one face only. The working edges are either straight or curved, the latter predominating. In these, the concave side is seen to be formed by a large, shallow, negative flake scar (fig. 4, Nos. 24 and 28). In view of the repetition of this feature in a number of cases, there seems little doubt that the flake was removed intentionally in order to procure a curved edge to the implement. This is further supported by the fact that subsequent scaling is invariably present.

(8) *Blades and Sinew Frayers.*

In addition to the implements described above, there are also a few untrimmed blades, 10 complete and 36 fragments, together with 33 of the artefacts which have been described from the Upper Kenya Aurignacian as "sinew frayers" (5) (fig. 5, Nos. 1, 2, 3, and 4). These call for no particular description. The blades are asymmetrical in form although all are relatively long and thin, with very little retouch, or more commonly none at all. The "sinew frayers" are comparable in every respect to those described from the Aurignacian.

(9) *Utilised Flakes.*

Some 1381 flakes and fragments were recovered which cannot be assigned to any tool types, but which in all cases exhibit more or less intensive utilisation and sometimes slight retouch. In addition there were found

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Flakes showing Battered Utilisation, "Triangular Fabricators": (6) C. IIIb, L/2, 0·5540; (7) C. VIII, L/2, 0·5957.

Core, utilised as Hammerstone: (8) C. I, L/2, 0·842.

Rolled Artefacts.

Backed Blade: (9) C. Ig, L/3, 0·2565. *Crescent*: (10) C. IX, L/3, 0·6012.

Fragment of Backed Blade: (11) C. IIc, L/3, 0·3464.

Large, heavily rolled Flake showing a "clacton" type cone of percussion and incipient cones on the primary flake surface, due to battering in the beach. The ridges of the flake scars visible on the distal extremity are less heavily rolled than those on the remainder of the specimen and appear to be more recent. (12) C. III, L/3, 0·2021.

Bulbar Extremity of a Large Blade: (13) C. IIe, L/3, 0·5901.

Core: (14) C. IX, L/3, 0·6011. *End Scraper*: (15) C. II, L/3, 0·1749.

End Scraper on Blade: (16) C. Ie, L/3, 0·2344.

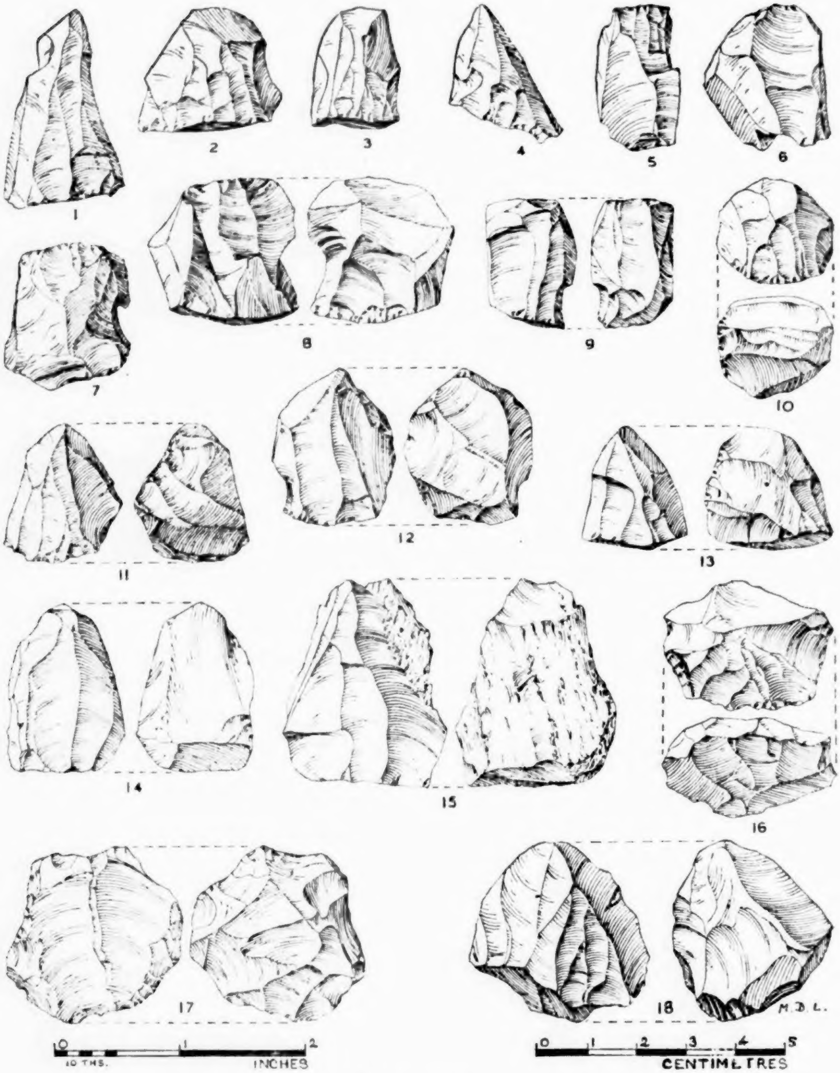

FIG. 6.—Cores.

Conical Cores. Type (a): (1) C. IIb, L/2, 0·4390; (2) C. IIIs, L/2, 0·6112; (3) C. III, L/3, 0·1833; (4) C. IIIc, L/2, 0·3596.

314 flakes and fragments characterised by the presence of one or more triangular ridges, which show on the crests, a battered or crushed utilisation (fig. 5, Nos. 6 and 7).

A proportion of these should undoubtedly be classified as regenerating flakes, but the occurrence of the so-called "triangular fabricators" previously described from the Kenya Aurignacian should be mentioned (6). In these, two or sometimes three ridges are present on which battered utilisation is to be seen. When this is present on three ridges it may be taken to indicate that the utilisation has taken place subsequent to the detachment of the flake from the core.

Although it is possible that the larger of these implements were in fact employed in the manufacture of crescents, this explanation does not appear to meet the case when the smaller specimens are considered.

(10) *Cores.*

The total number of cores recovered amounts to 381, of these 280 are complete and the remainder fragmentary. Five types may be distinguished which include minor variations within each category.

(*a*) Conical cores.
(*b*) 1, 2, 3, Double platform cores.
(*c*) "Uniface" cores.
(*d*) Discoidal cores.
(*e*) Spherical cores.

Type (*a*), *Conical* (fig. 6, Nos. 1–4).—64 examples. Average height 26 mm., ranging from 19–35 mm. Characterised by having a single striking platform, formed by either one truncated flake scar or, more frequently, by a series of small plunging scars struck from several directions. In most cases only two-thirds of the striking platform has been used for detaching flakes from; the scars are for the most part irregular and there is a complete absence of parallel fluted technique.

Type (*b*), *Double Platform Cores.*—These may be further subdivided into the following categories :—

(*b*1) (fig. 6, Nos. 5, 6, 7).—34 examples. Average length 27 mm.,

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Double Striking Platform Cores. Type (*b*1): (5) C. IIIc, L/2, 0·3613; (6) C. VI, L/2, 0·5906; (7) C. IIIs, L/2, 0·6116.

Type (*b*2): (8) C. IIs, L/2, 0·7157; (9) C. Vs, L/2, 0·6611.

Type (*b*3): (10) C. IV, L/2, 0·1887; (11) C. Ig, L/2, 0·2552; (12) C. IVc, I/2, 0·2755; (13) C. IIIc, L/2, 0·3599.

Uniface Cores. Type (*c*): (14) C. Ia, L/2, 0·2359; (15) C. IIc, L/2, 0·979.

Discoidal Cores. Type (*d*): (16) C. III, Ext. N. L/2, 0·2025; (17) C. III, Ext. N. L/2, 0·2024.

Spherical Core. Type (*e*): (18) C. Ic, L/2, 0·485.

ranging from 21–38 mm. In these cores the two striking platforms are at opposed ends, but the flakes are removed from the same face and are parallel in direction. In some examples the flake scars meet, forming a transverse median ridge, but more often they alternate, running the length of the core. The obverse faces exhibit truncated flake scars, struck prior to the preparation of the platforms, or sometimes a natural surface.

(*b*2) (fig. 6, Nos. 8, 9).—26 examples. Average length 28 mm., ranging from 27–45 mm. The two striking platforms are again at opposed ends of the cores, but the flakes have been removed from reverse faces, and are parallel in direction. One face of the cores invariably shows more intensive flaking than the obverse; three or more flake scars are, however, present on both faces, whilst occasionally unsuccessful attempts have been made to remove a flake from one lateral edge.

(*b*3) (fig. 6, Nos. 10–13).—22 examples. Average length 28 mm., ranging from 23–38 mm. In these cores the two striking platforms are at right angles to each other, the flakes struck from either platform being on opposed faces and approximately at right angles in direction. (Length measurements have been taken from the plane of one striking platform to the opposed lateral edge of the core.)

Type (*c*), "*Uniface Cores*" (fig. 6, Nos. 14, 15).—96 examples. Average length 32 mm., ranging from 20–52 mm. Only one striking platform is present on these cores and one face alone has been used to detach flakes, the obverse being cortex or a natural fracture. In shape they are usually triangular, the striking platform forming the base of the triangle.

Type (*d*), *Discoidal Cores* (fig. 6, Nos. 16, 17).—23 examples. Average maximum diameter 30·5 mm., ranging from 23–41 mm. These cores, usually circular in shape, show a prepared striking platform on the entire circumference. They are for the most part flat-sectioned and reminiscent of tortoise cores. The upper face, which is flat or slightly concave, exhibits two or more flake scars.

Type (*e*), *Spherical Cores* (fig. 6, No. 18).—15 examples. Average maximum diameter 29 mm., ranging from 20–39 mm. Three or more striking platforms are present on these specimens, resulting in the removal of flakes from three or more directions, the entire surface being covered by irregular, intersecting scars.

It will be seen that the average size of the cores is low relative to that of the implements and flakes and it is probable that the cores recovered represent discards, jettisoned as too small to be of further use. At sites such as Hyrax Hill, situated at considerable distance from suitable raw material, each core was in all probability worked down, increasingly small flakes being struck from it, till it became too small to be of further use and was then discarded.

The percentages of the above types to the total number recovered is as follows:—

(*a*) Conical	18	per cent.
(*b*1, 2, 3) Double Platform	22·4	,,
(*c*) Uniface	22·7	,,
(*d*) Discoidal	6·2	,,
(*e*) Spherical	4	,,
(*f*) Broken	26·7	,,

Comparative Notes on the Industry.

In the following comparative notes on the relationship of the Hyrax Hill industry to other industries previously discovered in the Rift Valley area near Nakuru, mention will chiefly be made of the Upper Kenya Aurignacian Phases B and C, the Elmenteitan, Wilton A, Gumban A and Gumban B. Short descriptions of all these industries have been published in "Stone Age Cultures of Kenya Colony," but it should be noted that during recent years a considerable amount of additional material has been recovered, in particular from sites belonging to the Gumban A Variant of the Stone Bowl Culture. Moreover, I have partially excavated a rock shelter near Naivasha which yielded some 73,000 implements. This material has yet to be studied, but it clearly stands very close to the industry from Hyrax Hill and also to the Aurignacian Phases B and C.

Comparison with the Upper Kenya Aurignacian Phase B is undoubtedly of most value on account of the vast amount of material recovered from the 4th occupation level at Gamble's Cave. The Elmenteitan, Wilton A, and the Gumban A and B Variants of the Stone Bowl Culture have yielded less material to date, but enough is available from excavated sites to warrant their inclusion in these notes.

As has been stated in the description of the occupation level and cemetery, the finds, both of implements and potsherds, were for the most part derived from the layer of brown soil (layer 2) which underlay the level of large blocks of stone forming part of the mound structure. A relatively small number of implements and waste flakes were also recovered from the sandy soil and beach pebbles which formed the lowest stratum of the mound (layer 3). Since these are in an identical state of preservation to the series from layer 2, showing no traces of water action and, moreover, are typologically identical, the implements from both levels are described together.

In comparing the crescents to those of other cultures hitherto discovered in the same region, the greatest similarity is to be found in the Upper Kenya Aurignacian Phase C. Minor differences occur, mainly in the relative proportions of the types found in either industry, although the types themselves, with the exception of *lames écaillées*, are common to both.

There is a tendency for the backs to be more curved and consequently for the implements to be more truly crescentic in the Hyrax Hill series. The Gravette point, which occurs in the Aurignacian, is completely absent. The type of crescent showing a "bevelled" cutting edge is common to both industries, but is more numerous at Hyrax Hill. There is also a tendency for the series as a whole to be considerably smaller in size than the Aurignacian.

Crescents of the Elmenteitan, Wilton A, Gumban A and B are of greater width relative to length than in the Hyrax Hill series. A high proportion of the Elmenteitan crescents lack a dorsal ridge or *arrete*; this condition is extremely rare in both the Aurignacian and Hyrax Hill series, in which nearly all the specimens show one or more ridges. Bevelled edge crescents are not known in any of the four industries mentioned above.

Borers, obliquely trimmed points and backed blades of the non-crescentic type are comparatively rare in the Hyrax Hill industry. Borers appear to be very scarce in the Aurignacian, Wilton A, and Gumban A and B, although some have been found in the Elmenteitan. In this industry, as in the Gumban B, non-crescentic backed blades constitute the most common type of implement belonging to this category. No obliquely trimmed points have been found in association, although they are well represented in the Aurignacian.

The occurrence of micro-burins provides another link with the Aurignacian, since, although common to both industries but more common at Hyrax Hill, none have been found at sites belonging to any of the other industries. The Hyrax Hill examples are perhaps smaller in size than the Aurignacian, but appear to be identical in type.

In the burins a great similarity is again to be found. "*Bec-de-flute*" and all forms of angle burins which characterise the Aurignacian are represented at Hyrax Hill. In the Aurignacian, however, a number of "*bec-de-perroquet*," polyhedric, "*busqué*," and "*appointé*" burins occur. These types have not been found at Hyrax Hill. "*Burins plans*" and the particular type of recurving angle burin described in this paper are more numerous than in the Aurignacian. Burins are rare in the Elmenteitan. Those which have been found include a few angle burins, but on the whole they are crude and atypical; this also applies to the Wilton A and to the Gumban A and B.

Less variety is to be found in the scrapers than in those of the Aurignacian, and for the most part they are more asymmetrical and not so well made. Simple end scrapers are the most common form, square and double-ended examples being exceedingly rare. The latter are generally made on narrow blades. No nosed scrapers nor any examples of the thumb-nail type, characteristic of the Wilton A, were found.

In the Elmenteitan and the Gumban A and B, scrapers, like burins, are

not numerous. The Elmenteitan specimens are generally made on long blades, whilst in the two Variants of the Stone Bowl Culture they appear to be almost entirely confined to small crudely made end scrapers. In addition to the thumb-nail scrapers which are characteristic of the culture, a few larger, rather crude specimens are also found in the Wilton A.

The occurrence of *lames écaillées* provides a feature common to the Elmenteitan, Wilton A, and Gumban A and B, but not recorded from the Upper Kenya Aurignacian Phase B but occurring in Phase C. They may in fact be said to be non-existent in this stage of the culture, on account of the very large assemblage of that industry which was recovered from Gamble's Cave, wherein no example of a *lame écaillée* was found. They are, however, relatively scarce at Hyrax Hill, while in the Elmenteitan and Gumban A they are so numerous as to constitute a type tool.

Of the utilised flakes, little need be said with the exception of the triangular form showing battered or crushed utilisation on the edges. In these, a further link is supplied with the Aurignacian since they are a type found in great abundance in that industry and have, in fact, been described as "Aurignacian fabricators." They appear to be absent or very scarce in the other industries under review.

Likewise the exceedingly small number of untrimmed blades cannot be regarded as at all significant. "Sinew frayers" are common in the Aurignacian, but not known in the Elmenteitan or Wilton A or Gumban A. One specimen is recorded from the Gumban B, but this is believed to be intrusive. Whether or not these tôols are considered as having been put to the use suggested by the name, their presence or absence in certain industries may be significant.

Comparison of the cores is rendered impossible by the fact that none have been published from the other cultures.

An attempt has been made in the foregoing notes to summarise briefly the typological variations of the implements in the later Stone Age cultures and in the Variants of the Stone Bowl Culture hitherto discovered in the Rift Valley area. This comparison must necessarily be very incomplete in view of the scanty material available from some sites and of the ever-growing number of Stone Bowl Culture Variants which have been discovered within recent years, some of which do not appear to belong to any of the previously known industries. It is hoped, however, that this preliminary attempt may be of use and that, at some later date, it may be possible to amplify it and determine the relationship of all the industries in the area.

Little doubt can be entertained that the industry of the Hyrax Hill Variant of the Stone Bowl Culture is largely derived from the Aurignacian, either in the stage represented by the 4th Occupation level at Gamble's Cave or, more probably, from a later evolution of the same culture. The

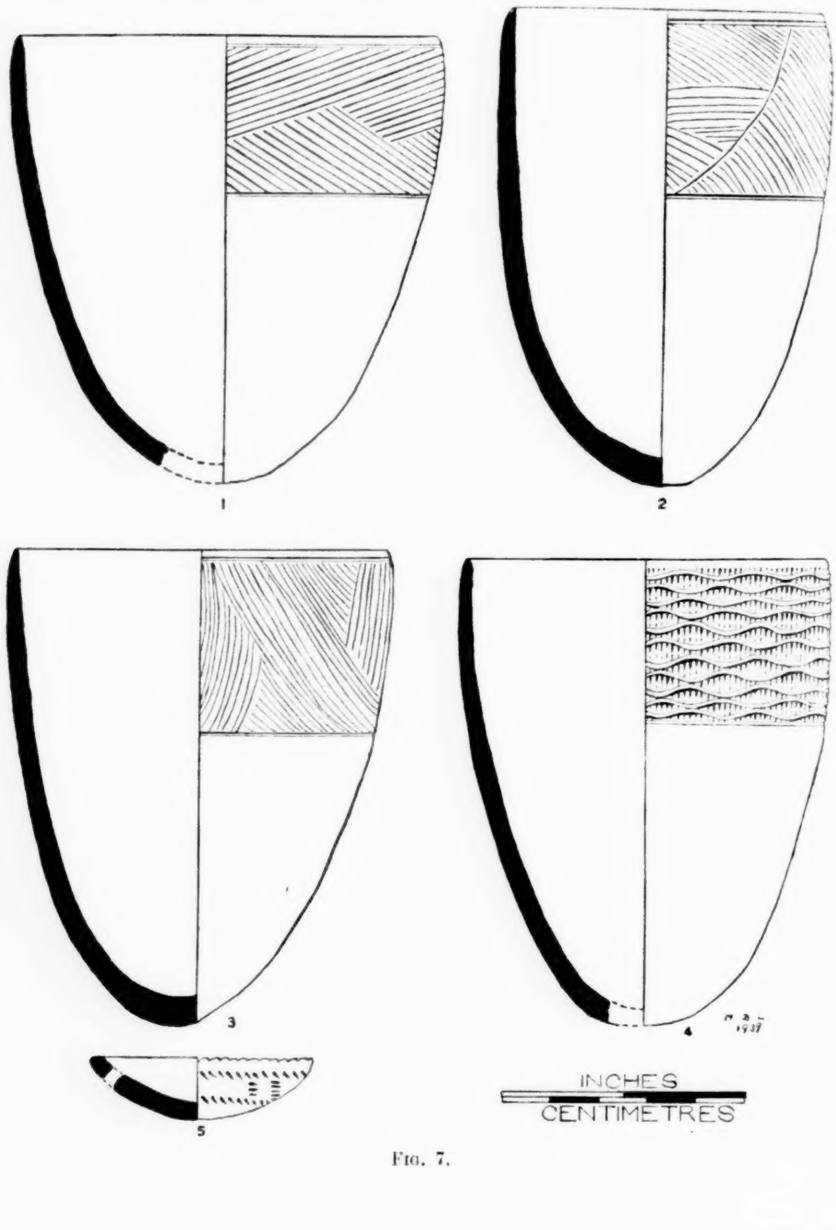

Fig. 7.

great similarity which exists cannot be regarded as fortuitous. Indeed, were it not for the associated stone bowls and pottery, the industry might well be described as a microlithic Aurignacian.

Description of Plate XI and Fig. 7.

No. 1. Ovoid beaker. Height 7·2 inches. The diameter of the mouth, which is the widest in the four vessels, measures 7 inches. The decorated zone, 2·6 inches deep, is situated immediately beneath the rim and is enclosed by two horizontal incised grooves. The comb pattern of intersecting panels is more regular and better executed than in Nos. 2 and 3, the grooves are better defined and broader, while those belonging to each panel are more exactly parallel. The ware is well fired, brownish red in colour, with a particularly smooth surface. From Cutting Ix, layer 2.

No. 2. Ovoid beaker. Height 7·4 inches. Diameter at the mouth *circa* 5·2 inches (only a small section of the rim is preserved). Comb decoration of intersecting panels which are divided from one another by diagonal incised lines. These extend the width of the decorated zone, which is 2·4 inches deep and lies immediately beneath the rim. It is confined by two horizontal incised grooves. On the interior, the surface of the vessel is much weathered and the exterior is very variable in colour, adjoining sherds being sometimes brownish black and light red. From Cutting Ib, layer 2.

No. 3. Ovoid beaker. Height 7·7 inches. Diameter of the mouth, which is slightly oval, 6 to 6·2 inches. Comb decoration of intersecting panels confied to a horizontal band 2·8 to 3 inches in width and situated immediately beneath the rim. This band is enclosed by two deeply incised horizontal lines. The walls of the vessel are irregular, one side being considerably more convex than the other. The ware is well fired and varies in colour from blackish brown at the base to reddish buff at the rim. The greater number of the sherds belonging to this vessel were derived from Cutting Ib, but a proportion were also recovered from Cuttings Ix, IIb, Ic, IIc, IIIc. All were from layer 2.

No. 4. Ovoid beaker. Height 7·4 inches. Diameter of the mouth 5·5 inches. The decoration zone, 2·6 inches in depth, is again placed immediately beneath the rim and is divided from the lower part of the vessel by a horizontal incised line. Unlike the other ovoid beakers, no groove exists between the rim itself and the decoration. This, which is unusually well executed, consists of a curvilinear trellis motif formed by eleven undulating ridges running horizontally, the elliptical spaces between the ridges being filled with small vertical impressions. The rim of this vessel tends to be more incurved than in Nos. 1 and 3. Both the interior and exterior surfaces are variable in colour, ranging from reddish black to reddish buff. The ware is moderately well fired and smooth surfaced. From Cutting I.

No. 5. Small perforated vessel with notched or "milled" rim. Height 0·9 to 1 inch. Diameter of the rim 3·1 to 3·2 inches. The decoration of intersecting lines formed by series of small oblong impressions covers the whole of the exterior, including the base. Only one perforation is preserved, but it seems probable that a duplicate hole was originally present on the opposite side of the vessel and one has been placed there in the reconstruction.

The presence of decoration over the whole exterior, together with the perforation made in the wet clay which precludes the possibility that it might have been a repair hole, suggests that this small saucer-like vessel may have been suspended or been used as a cover. From Cutting IIb.

Elmenteitan influence is perhaps to be seen in the occurrence of *lames écaillées*, although these implements may have been in use during the final stages of the Aurignacian.

2. The Pottery.

General Description.

Some 1350 potsherds were recovered from the occupation level. With the exception of 19 fragments found among the beach pebbles of layer 3, all were obtained from layer 2.

Among these sherds 28 distinct vessels may be distinguished on the basis of rim types, decoration and paste. Five of these are sufficiently complete to render reconstruction possible.

The pottery is all hand-made and extremely simple. The most common pot form appears to have been an ovoid beaker such as those which are shown in fig. 7 and in Plate XI, Nos. 1–4. It seems that vessels of this type should be regarded as characteristic of the Hyrax Hill Variant of the Stone Bowl Culture. One bowl-like vessel with incurved rim was also found (fig. 9, No. 4), together with a small flat perforated saucer (fig. 7, No. 5) and fragments of a large straight rimmed vessel (fig. 9, No. 5). No applied spouts, handles, lugs, or bosses were found.

The rim types are primitive and only two forms are represented in the series of twenty-eight vessels, twenty-three of which have the rim preserved. The straight or slightly incurved form which is characteristic of the four reconstructed beakers is also present on thirteen of the fragmentary vessels. Five examples were also found of the bevelled rim such as is shown on the bowl-like vessel.

Owing to the fact that in some cases rim fragments known to belong to the same vessel vary considerably in thickness and colour and to the uneven nature of the wares, no subdivision of the two rim types is attempted in the present paper. It will be seen, however, that slight variations within the two categories do occur, the straight rims in some cases being square sectioned and in others round or nearly pointed. Likewise the bevelled rims also vary, some being more everted than others.

Bluntly conical, flat, and the "knobbed" base, terminating in a small projection, which is also characteristic of the Elmenteitan, are all represented among the half-dozen bases which were recovered. The blunt conical type appears to be characteristic of the ovoid beakers and accounts for four examples. These, together with the knobbed bases, are formed by a small roughly circular disc of clay which shows on the circumference, a convex cleavage surface due to the method of manufacture which is described below.

A decorated flat base which belongs to a vessel of unusually thin ware is shown in fig. 8, No. 24, together with the knobbed and conical examples (Nos. 26 and 27).

The method of manufacture employed for this pottery appears to have been almost entirely that of the coil or ring technique. The majority of the sherds recovered show horizontal fractures, either convex (lower edge) or concave (upper edge). These are due to breakage along lines of weakness at the junctions of the successive coils or rings of clay from which the vessels were built up.

In colour the sherds vary considerably, ranging from black and grey-brown to light buff. The inner and outer surfaces are generally of the same colour except in the case of basal fragments which have become blackened through subsequent firing. In texture, the wares are uniformly smooth to the touch, although sometimes cracked and pitted through weathering. The "sand-paper" surface characteristic of the Iron Age and North-East Village pottery is never found. The sherds are on the whole moderately well fired, but thick coarse gritted wares such as that of the vessel shown in fig. 8, No. 18 are markedly less so than the average and consequently more brittle.

Traces of red slip are present on one vessel which is shown in fig. 8, Nos. 10 and 11. This vessel, moreover, exhibits the only example of a carination among the sherds. No perforations drilled after firing were found, in fact the sole example of a perforation is that shown in the small shallow saucer mentioned above, in which the edges of the hole are pushed out on to the external surface of the vessel, demonstrating that it was made before firing took place.

Decoration.

All the decoration has been carried out prior to firing. It includes a wide range of different incised and impressed motifs. Among these are impressed dots, applied in concentric lines and herring bones; impressed triangles, applied in parallel lines or rectangles; ridged "all-over" decoration formed by parallel lines of toothed impressions; thumb-nail; comb; and lastly, incised lines, either straight or curved. Detailed descriptions of these motifs are given in the descriptions of Plate XI and of figs. 8 and 9.

Vessels of the ovoid beaker type appear to have had the decoration confined to a horizontal band immediately beneath the rim. The bowl shown in fig. 9, No. 4 has, on the other hand, three zones of decoration, two of which are separated by plain bands with the bottom zone apparently extending to the base itself or within a short distance of it. The fact that two of the fragmentary vessels with bevelled rims also appear to have had decoration extending beyond the rim zone usual in the beakers, may possibly

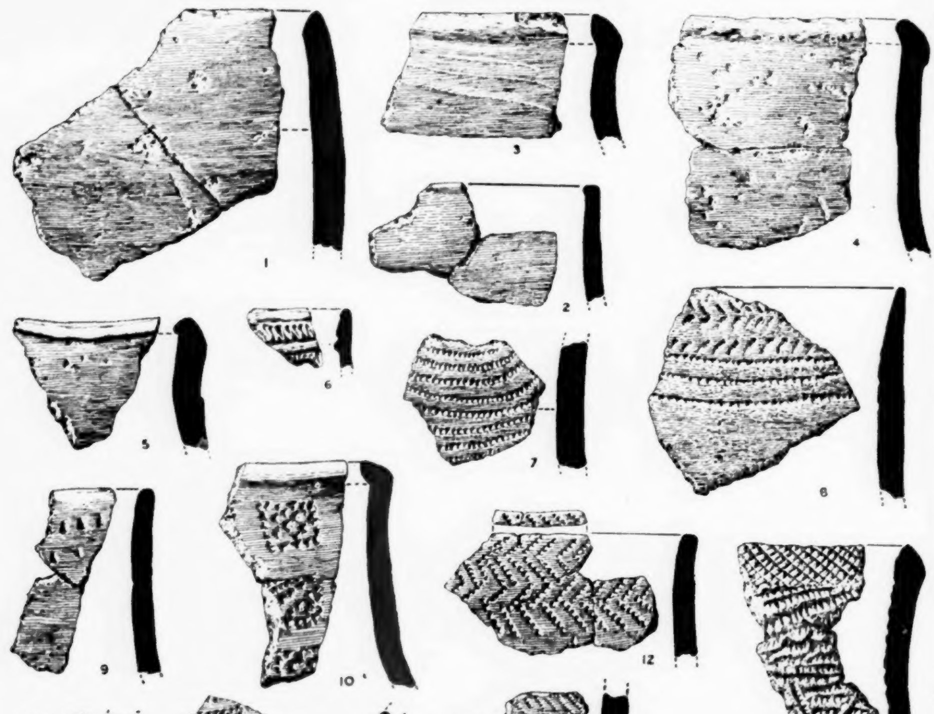
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FIG. 8.

Description of Sherds in Fig. 8.

No. 1. Straight rim, slightly inverted; blackish-brown ware with coarse grits. From Cutting III, Extension N, layer 2. (Cat. No. P. 1107.)

No. 2. Straight rim, square sectioned. With a slight external lip. Reddish-brown, fine-gritted ware. From Cutting II, layer 2. (Cat. No. P. 1094.)

No. 3. Bevelled rim, well-fired hard ware, reddish brown in colour with fine grits. The slight ridges visible on the exterior are due to tooling of the surface. From Cutting IVs, layer 2. (Cat. No. P. 1780.)

No. 4. Bevelled rim. Heavily gritted brown ware, both surfaces much weathered, very uneven in thickness. From Cutting IV, layer 2. (Cat. No. P. 392.)

No. 5. Bevelled rim slightly rolled, uneven, possibly belonging to the same vessel as No. 4. The paste is the same but the sherd less weathered. From Cutting IVs, layer 2. (Cat. No. P. 1781.)

No. 6. Small fragment of a straight rim with a decoration of impressed, oblique lines combined with a horizontal ridge, very similar to the decoration of the ovoid beaker No. 4, Pl. III. Fine, blackish-brown ware. From Cutting IIe, layer 2. (Cat. No. P. 2145.)

No. 7. Sherd showing a decoration of large impressed dots in roughly concentric lines. Very similar to the decoration of No. 2, fig. 9. Reddish-buff ware with coarse grits, well fired. From Cutting IIIb, layer 3. (Cat. No. P. 1969.)

No. 8. Straight rim with a decoration of three horizontal dotted lines below oblique and herring-bone impressions. Well-gritted black ware, exterior surface very weathered, interior brownish black in colour. From Cutting IVs, layer 3. (Cat. No. P. 1838.)

No. 9. Straight rim, slightly inverted, with a decoration of irregularly placed triangular impressions. Light buff ware with fine grits. From Cutting III, layer 2. (Cat. No. P. 1132.)

No. 10. Bevelled rim with a decoration of triangular impressions applied in rectangles. The paste is black and almost gritless, traces of a red slip are present. From Cutting Vs, layer 2. (Cat. No. P. 1898.)

No. 11. Fragment of carination belonging to the above vessel, the red slip is better preserved on this sherd. From Cutting IVc, layer 2. (Cat. No. P. 953.)

No. 12. Straight, square-sectioned rim, showing a herring-bone decoration of impressed dotted lines. Diagonal impressions of groups of three dots are also present on the upper surface of the rim. Blackish-brown ware, well fired, with a smooth surface. From Cutting IVs, layer 2. (Cat. No. P. 1837.)

No. 13. Bevelled rim showing a decoration of criss-cross incised lines on the exterior, below which, on the wall of the vessel, are "toothed impressions" forming oblique parallel ridges, sometimes interrupted by an intersecting ridge. This type of decoration is similar to that found on Gumban A vessels from Stable's Drift and the Makalia Burial Site, Elmenteita (7). None of the Hyrax Hill sherds, however, exhibit the internal scoring which is present in the Gumban A Variant of the Stone Bowl Culture. The ware is well fired and gritted, reddish buff in colour with black core. From Cutting Vs, layer 2. (Cat. No. P. 1896.)

No. 14. Thick sherd of fine-gritted buff ware with impressed thumb-nail decoration. From Cutting III, Extension N, layer 2. (Cat. No. P. 395.)

No. 15. Sherd of reddish-brown ware with fine grits showing a lightly impressed dotted herring-bone decoration. From Cutting IIe, layer 2. (Cat. No. P. 216.)

No. 16. Sherd showing an impressed dotted decoration of three parallel lines above a

series of oblique or nearly vertical wavy lines of dots. Gritty ware, buff coloured on the interior and grey-brown on the exterior. From Cutting IIb, layer 2. (Cat. No. P. 986.)

No. 17. Sherd of black, smooth-surfaced ware showing four lightly incised parallel lines. From Cutting II, layer 2. (Cat. No. P. 1025.)

No. 18. Thick, slightly incurved rim with a decoration of small vertical impressions applied in discontinuous horizontal lines. Coarse ware of uneven thickness; brittle and ill-fired, with large, rather sparse grits. Colour variable on both surfaces, from reddish buff to grey. From Cutting IV, Extension N, layer 2. (Cat. No. P. 1209.)

No. 19. Decorated sherd of the above vessel. Note the concave cleavage surface on the lower edge. From Cutting III, Extension N, layer 2. (Cat. No. P. 1155.)

Nos. 20–24. Sherds probably belonging to one vessel of unusually thin and well-fired black ware with burnished surface. No. 20 shows the straight rim; No. 21 the curve which is present on several sherds and which suggests that this vessel may have had a slight shoulder; Nos. 22 and 23 show the decoration of incised straight lines and small elongate impressions, whilst No. 24 represents the flat base of this vessel, decorated with two parallel lines of vertical impressions. No. 20 from Cutting Ia (Cat. No. P. 40); the remainder from Cutting I, layer 2 (Cat. Nos. P. 14, 22, 19, 16 respectively).

No. 25. Straight, thick rim of gritty black ware with a decoration of broad diagonal lines, formed by successive small curved impressions; traces of a second diagonal line are visible below the first. From Cutting IIIc, layer 2. (Cat. No. P. 1290.)

No. 26. "Knobbed" base. The convex cleavage surface on the circumference, mentioned above, may be seen in this specimen. Blackish-red, well-fired ware with fine grits. From Cutting Ic, layer 2. (Cat. No. P. 119.)

No. 27. Base, of the bluntly conical type; this specimen also shows the convex cleavage surface on the circumference of the sherd. Buff-coloured ware with fine grits. From Cutting IV, layer 2. (Cat. No. P. 390.)

Description of Fig. 9.

No. 1. Represents a vessel some 6 inches in diameter at the mouth, probably belonging to the ovoid beaker type. The decoration, just below the rim, is composed of a series of three roughly concentric incisions, approximately the shape of the lower half of an ellipse which has been cut diagonally to its length. These three incisions, butting at each end on to the rim, are in every case closer together at the right extremities than at the left, where the strokes appear to have begun. The axis on which the motif is based falls away to the right, at roughly 65° to the rim. The ware of this vessel is brown, with patches of black; smooth surfaced and well fired. From Cutting VII, layer 2. (Cat. No. P. 1436.)

No. 2. A number of sherds belonging to the beaker type with slightly incurved rim, approximately 5 inches in diameter at the mouth. The impressed decoration consists of a series of half-circles formed by thirteen concentric lines of dots and is similar in general motif to that of No. 1 although executed with considerably more care. The ware is well fired, varying in colour from red to brownish black on the exterior. The interior is uniformly grey-brown. Faint vertical striations on the exterior indicate that the smoothing of the surface was carried out from a perpendicular direction. From Cutting I, layer 2. (Cat. No. P. 34.)

No. 3. Adjoining sherds belonging to a vessel of unusually thick, uneven ware, some 4¾ inches in diameter at the mouth, tapering rapidly towards the base. The decoration of three horizontal lines formed by impressed lozenges is exceedingly irregular. The rim sherds are reddish brown in colour on both surfaces, while those approaching the base are the same colour on the outside, but black on the interior. The ware is well fired and

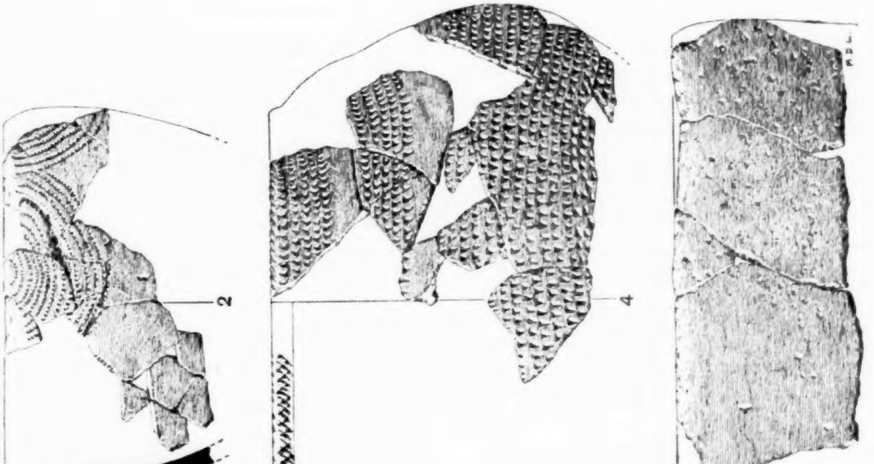

Fig. 9.

indicate a different location of the decoration in the two types of vessel distinguished by straight and bevelled rims.

Only two vessels show decoration extending on to the inner surface of the rim (fig. 8, No. 12 and fig. 9, No. 4).

For the most part, the motifs are irregularly executed, the ovoid beaker shown in Plate XI, No. 4 and the carinated vessel shown in fig. 8, Nos. 10 and 11 are exceptional in this respect, since considerable care and regularity is shown in the application of the decoration in both cases.

Comparative Notes on the Pottery.

In the following comparative notes only the pottery of the Mesolithic and Neolithic cultures within the Nakuru region will be considered, namely, the Elmenteitan, the Wilton A, and the Gumban A and Gumban B Variants of the Stone Bowl Culture.

Satisfactory analogies in form are lacking, since the distinctive ovoid beakers and the small perforate saucer are both types hitherto unknown from Kenya prehistoric sites. The highly decorated bowl does, however, bear a strong resemblance to the internally scored bowls of the Gumban A people. It is not an exact parallel since it appears to fall midway between the Gumban A bowls with incurved rims and those wherein a definite shoulder is present, together with a straight or slightly everted rim.

Large vessels of the type shown in fig. 9, No. 5 are known to occur in the Elmenteitan, while recently a complete specimen has been recovered from Njoro River Cave.

Straight, or slightly incurved, rims appear to have been the most widely used form in the district during Mesolithic and Neolithic times and outnumber all other types in the industries under review. The fact that all

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large grits can be seen. Sherds of this vessel were remarkably scattered, being recovered from Cuttings I, IIIc, IV, and V. (Cat. Nos. P. 2108, P. 115, P. 1256, and P. 1269.)

No. 4. Represents a highly decorated bowl with incurved rim, approximately 5¾ inches in diameter at the mouth. The bevelled interior surface of the rim is decorated with crossed incisions, while on the upper edge a further series of oblique incised lines is present. The decoration of close-set triangular impressions lying beneath the rim and on the body of the vessel is applied in three zones with two intervening plain bands. This is entirely similar to the decoration seen on the internally scored bowls of the Gumban A Variant of the Stone Bowl Culture. The ware is reddish brown in colour with sparse grits. Sherds of this vessel were recovered from three adjacent cuttings, namely, IIc, IIIc, and IVc. (Cat. Nos. P. 896, P. 1275, and P. 948.)

No. 5. Five adjoining fragments of a large straight-rimmed vessel of which the diameter of the mouth is calculated to be 13¾ inches. Both surfaces are much pitted and weathered, the interior in particular. The ware is greyish buff in colour, with fine grits. From Cuttings IIb and IIc. (Cat. Nos. P. 301 and P. 903.)

rim sherds of the Wilton A which have hitherto been recovered are uniformly thick and straight should be mentioned. Those found in the remaining industries are variable as at Hyrax Hill.

Bevelled rims are markedly characteristic of the Gumban A internally scored bowls and frequently show oblique incisions on the upper edge, similar to those on the vessel from Hyrax Hill. Similar rims are also usual in the Elmenteitan. In the Gumban B, on the other hand, only simple straight rims have so far been found.

Round, conical, and flat bases all occur in the Elmenteitan, some of which approach very closely to the ovoid beaker bases. From the Gumban A, only those bases which belong to the internally scored bowls are known. These are generally round but sometimes tend to become somewhat conical. No bases are known from the Wilton A, while those from the Gumban B are either round or conical.

Evidence of the coil or ring method of manufacture which is commonly found in the Hyrax Hill sherds is equally noticeable in the Elmenteitan pottery, the Wilton A, and the Gumban A. In the Gumban B, however, such sherds are comparatively rare.

The Elmenteitan, Wilton A, and Gumban A wares, in common with those from Hyrax Hill, are characterised by the smooth, rather soapy feel of the surfaces which is entirely distinct from the Hyrax Hill Iron Age pottery and from most of that recovered from the North-East Village, which may be considered to be closely related to the Gumban B.

The occurrence of both smooth- and rough-surfaced wares in this last industry, coinciding with the first known appearance in the district of spouts, handles, and impressed cord decoration, suggests the possibility that the Gumban B Variant of the Stone Bowl Culture represents a transitional stage between the earlier smooth-surfaced wares and the later rough-surfaced wares which are markedly better fired and better welded along the coil junctions.

Perforations made in the wet clay before firing, similar to that of the small perforate saucer from Hyrax Hill, are known in the Elmenteitan and Gumban A. In the former, as in the Wilton A and Gumban B, repair holes are also common.

It is obviously impossible in the space of these notes to give a detailed description of the large number of different decorative motifs which are known from the industries under review and only the main types will be discussed.

The decoration of the Elmenteitan pottery is very simple and shows little variety. The principal motifs are: "punch" holes, probably made with a broken reed or grass stem; series of short, parallel incised lines, applied in rows; small lozenge impressions, and lastly, notched, or milled rims.

Only one type of decoration has so far been discovered in the Wilton A, namely, a single, incised wavy line. This is illustrated in "Stone Age Cultures of Kenya Colony," p. 207.

It will be seen that with the exception of the notched rims in the Elmenteitan, neither this culture nor the Wilton A provides decorative motifs comparable to those from Hyrax Hill. No significance can be attached to the occurrence of milled rims since these are found in nearly all the later cultures in the district, and persist into the Hyrax Hill Iron Age.

The greatest resemblance to the Hyrax Hill style of decoration is found in the Gumban A. In this industry a number of the motifs are identical to those from Hyrax Hill and, moreover, the variety is strikingly similar.

Among the motifs common to both are close-set triangular impressions, dotted herring-bone and a ridged "all-over" pattern generally found on the internally scored bowls of the Gumban A. Comb-decorated sherds are also found in both contexts, and also the small vertical impressions shown on the flat base from Hyrax Hill. Indeed, so great a similarity exists, both in texture and decoration, between the pottery of the Gumban A and Hyrax Hill Variants of the Stone Bowl Culture that a considerable number of sherds could be transposed without arousing comment; always excepting those of the Gumban A which exhibit internal scoring. In addition, red-slipped wares are common to both, although more rare at Hyrax Hill.

The Gumban B provides no close analogies, and although oblique incised lines and oblong impressions do occur, they are dissimilar. Moreover, applied spouts and handles are characteristic of this pottery, together with impressed cord decoration, which, as will be seen from the reports on the Hyrax Hill Iron Age and North-East Village, eventually became employed to the exclusion of nearly all other impressed and incised motifs.

It will be seen from the foregoing notes that, although differences exist, notably in the occurrence of the internally scored bowls and the prevalence of red-slipped wares in the Gumban A, this pottery provides the closest analogies to that from Hyrax Hill.

The affinities of the pottery assume added significance when it is realised that in the stone-bowl types and burial customs great similarities are also to be found. In fact, little doubt can be entertained that a close connection exists between these two Variants of the Stone Bowl Culture.

3. Sundry Objects recovered from the Occupation Level.

(1) *A Ground Stone Implement.*—A somewhat unusual stone implement made from basaltic lava, possibly phonolite, is shown in fig. 10. This implement appears to have been artificially shaped by grinding to a flattened cylindrical form. The butt end and cutting edge have been heavily damaged

through use, the latter being gouge-shaped and showing utilisation subsequent to the flake scars visible in view C. On the butt end a flat polished area is present, lying oblique to the length of the implement, this is shown in views A and B.

Although no evidence was obtained as to the purpose of this implement, it seems not improbable that it may have been employed in the manufacture

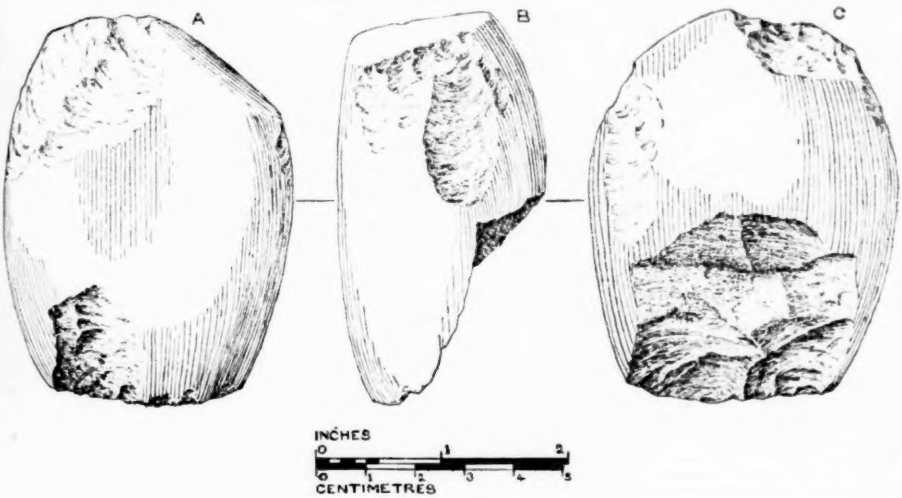

Fig. 10.

of stone platters, combining as it does, a gouge and a rubber, both of which would presumably be required for the purpose. No similar implements are known from the Kenya Neolithic or earlier cultures.

(2) *Hammerstones.*—These were exceedingly scarce in the occupation level and only four were recovered. One is illustrated in fig. 5, No. 8, and is unusual in that an obsidian core has been used. It shows extensive battering on all the edges. A second example, consisting of an irregularly shaped nodule of basement complex quartz, measures 2·3 inches by 1·5 inches in diameter. This was found in Cutting Is, layer 2. The third specimen, in which a phonolite pebble has been used, shows less battering than the other examples, it measures 2 inches in length and 1·7 inches in breadth, and was recovered from Cutting IVs, layer 2. The last specimen, which consists of a small pebble of vesicular lava, measures 1·9 inches in length and 1·4 inches in breadth. It is cylindrical in form and shows a

pecked utilisation on two opposite surfaces, similar to that on the small quartz pestle shown in fig. 13, No. 5. From Cutting Vs, layer 2.

(3) *Pebbles.*—Ten small chalcedony pebbles, about half an inch long, were also recovered. These appear to be derived from vesicles in the lava, and are probably of local origin. A small rectangular pebble of a substance known as pozolane was also found. This material occurs in the neighbourhood of Lake Elmenteita.

4. The Rolled Implements from the 335-Foot Beach.

Eight of these implements are illustrated in fig. 5 (Nos. 9–15). Although the series of 39 specimens is too small to be assigned to any particular culture, it includes certain forms which do not occur in the industry of the overlying occupation level, namely, large, thick-set backed blades such as those shown in Nos. 9 and 11. These specimens, although incomplete, average 14 millimetres in width, a figure greatly in excess of that for the backed blades from the occupation level, but quite usual among the backed blades of the Upper Kenya Aurignacian, Phase B. Similarly, no end scrapers on blades of the type shown in No. 16 of the same figure were found in the Neolithic assemblage.

The large flake showing a "clacton" type cone of percussion (No. 12) is interesting in view of the fact that this specimen, in common with the majority of the rolled series, appears to belong to the Njorowa Gorge obsidian and that similar flakes, showing the clacton technique, may be collected from the debris of the obsidian mines in the gorge.

On the geological evidence these mines cannot be earlier than the Upper Palaeolithic period and may well be of later date. It seems probable that the clactonian or anvil technique was employed by the miners as being the most suitable for the initial trimming of the obsidian blocks, and that some of the large flakes so obtained were afterwards transported to the living sites in addition to the blocks themselves.

5. The Neolithic Cemetery.

As has been stated, the stony structure of a number of adjacent low burial mounds was found to cover part of the occupation level at Site I. In this structure, formed by an almost continuous layer of large blocks of stone derived from the nearby scree, were found nineteen contracted interments which had been placed either upon the 335-foot beach, or, more commonly, in shallow graves dug into the beach.

A stone somewhat larger than the average contained in the beach was usually found at the edge of the graves with the skull placed against it, the result being that it lay at a slightly higher level than the rest of the body.

(See Sections G–G′ and H–H′.) Nine of the interments, which are likely to have been female, contained grave goods in the form of flat stone dishes or platters, occasionally accompanied by pestles. In one case only, No. 21, additional grave goods in the form of two beads and an obsidian knife were found with the stone platter.

Over each body a flat stone slab, measuring 2 to 4 feet in diameter had been placed. This was separated from the underlying remains by some 4 to 18 inches of soil. In a number of burials the soil beneath the capstone was found to be clayey and black in colour, quite distinct from the lower infilling of the graves which was indistinguishable from the brown loamy soil of the occupation level. A possible explanation of this phenomenon is that a small hollow may have formed below the capstones as the bodies decomposed and that such a hollow might subsequently become silted up by the infiltration of fine soil during rains. It should be mentioned that the clayey soil was only noticeable when excavations were carried out in the rainy season; in the case of graves dug during dry weather, no difference could be seen between the upper and lower grave filling.

Although the occupation level had been dug through in order to reach the beach on which the bodies were placed, traces of this disturbance could only be found in a proportion of the graves. Where it was not visible the soil removed from the graves may have been immediately replaced as filling and pressed down by the weight of the overlying capstones.

The soil in the immediate vicinity of the skeletons could always be distinguished since it was very light and dusty when dry, besides being grey in colour. (This phenomenon appears to be constant in Kenya Neolithic burial mounds and provides a most valuable indication of the presence of human remains.)

Large blocks of stone were found round the capstone of each grave, with smaller stones packed into the crevices; furthermore, in the areas which had escaped subsequent disturbance by the digging of the intrusive Iron Age burial pits, it was noticed that roughly circular lines of upright stones generally enclosed the structure of each burial. This feature was particularly well preserved in the isolated burial mound E, described on p. 323, where the majority of the encircling uprights had remained in position.

It seems probable that little or no earth was placed over the boulder layer covering the burials, since the earth filling the spaces between the blocks was almost indistinguishable from that overlying the occupation level where no burial structure existed and was also practically barren of cultural remains. If the soil overlying the burials had been placed there by artificial means at the time of construction, it seems likely that it would have contained some contemporary objects. Moreover, the stone bowl fragments which were recovered from this level proved to be of a type known to belong

to the Gumban B Variant of the Stone Bowl Culture, but not found in the occupation level or in the burials, where all the stone vessels were exclusively of the platter type.

It should be mentioned that with the possible exception of No. 31, the burials in the northern part of the cemetery were invariably found in well-defined graves, while those to the south lay on the surface of the beach. Although this fact is not necessarily significant, it may perhaps indicate a slight change in burial custom. Had the depth of the occupation stratum been noticeably greater where no graves were found, it might be argued that these burials were of a somewhat later date and had taken place when a sufficient quantity of occupational debris had accumulated for the required depth to be obtained in the soil alone, without penetrating into the underlying beach. In view of the uniformity in depth of the occupation level, as may be seen from the sections in Plan II, the above explanation can only be regarded as a possibility.

The occurrence of disarticulated or "reserved" burials in the cemetery, such as Nos. 11 and 21, in which only the skull, arm, and leg bones were found, provides an interesting feature. These are comparatively well preserved and it therefore seems improbable that the remaining parts of the skeletons had decomposed. On account of the method of burial, which involved considerable space between each interment, it is not reasonable to suppose either that these bodies were disturbed in order to make way for fresh burials. That intentional disturbance did take place in the event of a dual burial within one grave is demonstrated by the remains of Nos. 4 and 5 and of 1 and 2 in Mound E. In these two cases it seems that a grave already containing one body was reopened in order to receive the remains of a second individual, the primary burial being greatly disturbed and displaced in the process.

A possible explanation for these reserved burials is that the site represents a tribal or family cemetery in which it was considered essential for all persons connected with the family or tribe to be buried. If this was the case, the remains of an individual who for one reason or another died at some distance from the home site may have been temporarily buried elsewhere and subsequently exhumed in a skeletal condition in order that the skull and limb bones, which were presumably considered sufficient to represent the individual, might finally be interred in the cemetery.

6. The Skeletons.

Note.—The numbers of the skeletons described below are not consecutive, since the human remains were numbered as found. The intervening numbers therefore refer to the intrusive Iron Age pit burials.

H.H. 1 (*Cutting Ix, northern part*), *Pl. XII, No.* 4.

Articulated skeleton buried in the contracted position on the left side, facing north. Both arms and both legs were flexed. Traces of the left wrist bones were found beneath the facial region of the skull. A large stone platter (Pl. XVI, No. 2 and fig. 12, No. 1) was found at a slightly higher level than the body, partly resting on the spinal column below the shoulders. In addition, a pestle of garnet gneiss (fig. 13, No. 3), was found beneath the right ankle. The skeleton appeared to have been placed upon the beach and not in a grave. It was covered by a large stone slab and lay at a depth of 4 feet from the surface. A layer of black soil 6 to 8 inches in thickness was found immediately above the remains.

H.H. 2 (*Cutting Ix*), *Pl. XII, No.* 5.

Articulated skeleton buried in the contracted position on the left side, facing north. The skull was much crushed and lay face downwards. All the extremities of the long bones had perished with the exception of those belonging to the right humerus, radius, and ulna. The femora, tibiae, and fibulae lay almost parallel to one another. The arms were flexed with the radius and ulna of the right arm lying parallel to the leg bones. The skeleton had been placed upon the beach material at a depth of 3·4 feet from the surface and was covered by a layer of black soil 3 to 6 inches in thickness. This was overlain by a slab of rock 3 feet long and 2½ feet wide. No associated grave goods were found.

H.H. 3 (*Cutting Ie*), *Pl. XII, No.* 6.

Fragmentary skeleton represented by the femora, tibiae, one humerus, radius and ulna, and traces of the mandible. The remains had been extensively gnawed by rodents. The femora and tibiae lay parallel to one another and appeared to have been articulated. The skeleton seemed to have been placed on the left side in the contracted position and faced north-west. It lay on the beach material at a depth of 3·2 feet from the surface and was covered by a localised layer of black soil, 2 to 3 inches thick, over which had been placed a rock slab 2 feet long and 1½ feet wide. No associated grave goods were found.

H.H. 4 *and* 5 (*Cutting III, north-east corner*), *Pl. XIII, Nos.* 1 *and* 2.

The fragmentary remains of Skeleton H.H. 4 were found resting on the articulated skeleton of H.H. 5 and lay in the following positions relative to the latter: the femora lay respectively on the spinal column and immediately west of the right radius and ulna of No. 5. The tibiae, which were

not articulated to the femora, lay respectively on the right tibia and immediately east of the lumbar vertebrae of No. 5. The skull fragments were found scattered over the ribs and spinal column, while the mandible rested on the sacrum. Two small pieces of humeri were also found among the skull fragments.

The articulated skeleton H.H. 5 was one of the best preserved found in the cemetery, although the skull is unfortunately warped. It lay in the contracted position on the left side, facing west. The skull faced downwards and the left side rested on one of the stones forming the circumference of the grave.

These two skeletons were covered by a rock slab measuring 3½ feet in length and 2½ feet in width and lay at a depth of approximately 4 feet from the surface. The soil intervening between the bodies and the capstone measured 6 inches in thickness.

The relative positions of these two skeletons approximate closely to those of the two skeletons which were found in the isolated burial mound E, which is described on p. 325.

H.H. 6 (*Cutting III*), *Pl. XIII, No.* 3.

The position of this immature skeleton differed in certain respects from the other eighteen interments in the cemetery. It had apparently been placed in an upright sitting position facing east and not, as was usual, laid on the left side. The cervical vertebrae, upper ribs, clavicles and scapulae lay beneath the skull, the first in a vertical position. The humeri were found lying to the south-east and south-west of the skull respectively, the arms being flexed. The knees were drawn up towards the chin with the right femur, tibia, and fibula overlying those of the left leg.

The skull, which was considerably crushed by an overlying rock slab, lay approximately in the Frankfurt plane. The skeleton lay in a shallow grave which had been dug into the beach material at a depth of 5·2 feet from the surface. It was covered by 3 inches of brown soil, over which lay a rock slab 3 feet long and 2½ feet wide. No associated grave goods were found.

H.H. 10 (*Cutting I*), *Pl. XIII, No.* 4.

Fragmentary skeleton. The skull, which did not appear to lie in a natural position relative to the body, was placed face downwards with the frontal to the south. The femora lay parallel to one another with the distal extremities 2 or 3 inches from the occipital and behind it. The tibiae also lay nearly parallel to the femora. The arm bones were represented by merely a few fragments of the humeri. A fragmentary stone platter was found lying on the leg bones (fig. 3, No. 12).

Although the skeleton was represented by such fragmentary remains that any conclusions as to the original relationship of the bones must be problematical, the relative positions of the skull and femora suggests that it may possibly have belonged to the "reserved" class of interment, such as Nos. 11 and 21.

The remains were found in a shallow grave which had been dug into the beach and lay at a depth of 4½ feet from the surface, covered by 6 inches of black soil, overlying which was a rock slab, 3½ feet long and 2 feet wide.

H.H. 11 (*Cutting I*), *Pl. XIII, No.* 5.

Disarticulated or "reserved" burial. The skull lay on the left side and faced south-east. The humeri, femora, tibiae, and fibulae lay nearly parallel to one another, the femora being superimposed with the distal extremities lying some 4 to 7 inches from the proximal ends of the tibiae and the proximal ends some 6 inches distant from the base of the skull. Owing to the fact that the bones recovered were in a fair state of preservation, it may be regarded as significant that no traces of the scapulae, vertebrae, ribs, or pelvic bones could be found. The remains lay in a shallow grave dug into the beach and were accompanied by a small stone platter (fig. 12, No. 2). A quartz pestle (fig. 13, No. 1) was also found in the grave, together with a decorated potsherd belonging to the ovoid beaker shown in Pl. XI, No. 4.

A localised layer of black soil, 2 to 3 inches thick, covered the bones. These lay at a depth of 3½ feet from the surface and were overlain by a triangular shaped rock slab measuring 3 feet in length and 2¼ feet in width.

No traces of disturbance subsequent to the sealing of the grave could be discerned, and it would seem that the unnatural relationship of the cranium and limb bones, together with the fact that some parts of the skeleton were completely missing, must be taken to indicate that the remains were placed in the grave in a disarticulated or skeletal condition. The parallel arrangement of the limb bones and the fact that the skull was placed on the left side suggests an attempt to arrange the bones in the position habitual for the articulated burials in the cemetery.

H.H. 21 (*Cutting IV*), *Pl. XIII, No.* 6.

Disarticulated skeleton. The skull, which was much crushed, lay on the left side facing north. The vertebrae and ribs were entirely missing, as were the clavicles, scapulae, and pelvic bones. One humerus was found lying in an isolated position, over 1 foot removed from any possible natural position and some 6 inches higher than the other bones. The leg bones likewise appeared to be disarticulated, with one tibia lying across the femora

shafts and the proximal articular end 7 to 9 inches distant from the distal extremity of either femur.

An exceptionally well-made stone platter was found resting on the limb bones (Pl. XVI, No. 2 and fig. 12, No. 1). An oblate disc bead and another small bead were also recovered from the soil near the skull, together with an unusually large crescent which was lying between the skull and limb bones.

The remains lay in a shallow grave at a depth of 4½ feet from the surface and were overlain by a slab of rock 4 feet long and 3 feet wide. Between the rock slab and the bones a layer of brown soil 8 inches thick was present.

As in the case of H.H. 11 and possibly of H.H. 10, it seems that the remains had been placed in the grave in a skeletal condition. Since there were no traces of disturbance visible, the isolated position of one humerus suggests that less care had been taken to place the bones in their appropriate positions than in the case of H.H. 11, although the character of the grave goods indicates that the individual was regarded as of some importance.

H.H. 22 (*Cutting IV*), *Pl. XIV*, *No.* 2.

Articulated skeleton buried in the ultra-contracted position, facing east. The left knee was found beneath the chin and the leg bones were almost exactly parallel to one another with the right leg overlying the left. Similarly, both humeri lay parallel to one another and to the leg bones, the arms being flexed with the right radius and ulna lying across the legs. Some of the bones of the left hand were found beneath the face, whilst the bones of the right hand lay upon the right tibia, extending to the knee. The ribs, vertebrae, and pelvic bones were in a fragmentary condition.

A small stone platter (fig. 12, No. 7) was found lying behind the skeleton in the region of the lumbar vertebrae. It rested partly against the side of the grave and was tilted inwards. The top of the skull also lay against the side of the grave, which was particularly well defined and measured 2·3 feet (east to west) by 2 feet (north to south) and 9 inches in depth. It is shown partly excavated in Pl. XIV, No. 1. The body lay at a depth of 4½ feet from the surface, being covered by 6 inches of soil and overlain by a rock slab measuring 3 feet in length and 2½ feet in width.

H.H. 23 (*Cutting IV, in part projecting into Cutting V*). (Not illustrated.)

A very incomplete skeleton, represented by the humeri, tibiae, and femora shafts, the teeth, one radius and ulna, and fragments of the pelvic bones. The body appeared to have been placed on the left side in the contracted position, facing west. The femora lay near one another with what appeared to be the right tibia overlying the left femur and tibia. A small ill-made stone platter (fig. 12, No. 9) was found immediately east of

the remains, resting against the side of the grave, together with a small rectangular quartz pestle shown in fig. 13, No. 5. This had been placed at the edge of the grave, west of the right tibia. The skeleton lay in an irregularly shaped grave which measured 2·7 feet maximum diameter (north to south) and lay at a depth of 3·9 feet from the surface. It was covered by 1·4 feet of soil, over which had been placed an elongate rock slab 4 feet long and 2 feet wide.

H.H. 25 (*Cutting V, partly in Cutting Ie*). (Not illustrated.)

Very incomplete skeleton represented by the femora and tibiae shafts, one piece of scapula, a few skull fragments and one upper molar. Although too fragmentary for certain identification, the positions of the bones, suggested that the body had been buried in an articulated condition. The remains lay at a depth of 4 feet from the surface in a well-defined grave which measured 2·9 feet (east to west) by 3·3 feet (north to south) and 1 foot in depth. Some 9 inches of soil intervened between the body and the covering slab of rock, which was 3 feet long and 2½ feet wide. No associated grave goods were found.

H.H. 28 (*Cutting V, north end*), *Pl. XIV, No.* 3.

Well-preserved articulated skeleton, buried in the ultra contracted position on the left side, facing south-west. The skull lay approximately in the Frankfurt plane. The knees were drawn up, the right knee lying in contact with the right clavicle. The femora lay parallel to one another and the legs appeared to have been crossed, since, although the right leg was uppermost, the left tibia crossed and lay on top of the distal half of the right tibia. The arms were flexed, with the right humerus projecting behind the body and the distal ends of the radius and ulna resting on the left humerus. This, together with the left radius and ulna, lay beneath the ribs and vertebrae. No grave goods were found and the body lay in an ill-defined grave at a depth of 3·7 feet from the surface. It was covered by some 6 inches of soil, over which lay a comparatively small rock slab 2½ feet long and 1¾ feet wide.

H.H. 31 (*Cutting Vs*). (Not illustrated.)

Very incomplete skeleton represented by one femur, the radii, ulnae and one fragment of humerus. The bones were extensively gnawed by rodents and the small fragments of human bone found scattered through the many rat holes in this cutting were probably derived from this skeleton. The remains lay in a well-defined grave measuring 2·3 feet (east to west) by 2·9 feet (north to south) and were found at a depth of 3·4 feet from the

surface. They were covered by a localised layer of black soil 3 inches thick, over which lay a rock slab measuring 2¾ feet in length by 2 feet in width. This burial was in a somewhat isolated position, as may be seen from Plan I. No grave goods were found.

H.H. 32 (*Cutting VII*). (Not illustrated.)

Incomplete skeleton represented by the femora, tibiae, teeth, and some skull fragments. The limb bones lay parallel to one another with the skull fragments to the east. A stone platter, which is shown in fig. 12, No. 4, was found behind the skull resting against the edge of the grave and tilted towards the body. The remains lay at a depth of 2·9 feet from the surface in a grave measuring 2·7 feet (north to south) by 2 feet (east to west). They were covered by 8 inches of brown soil over which lay an elongate slab of rock 4 feet long and 2½ feet wide.

H.H. 33 (*Cutting VIII*). (Not illustrated.)

Very fragmentary remains found in a shallow depression in the beach material at a depth of 2¾ feet from the surface. They were covered by 8 inches of brown soil over which had been placed a stone slab 3 feet long and 2½ feet wide. The bones were exceedingly broken and crushed, rendering identification and the determination of their positions impossible. No grave goods were found.

H.H. 36 (*Cutting IIIb*), *Pl. XIV*, *No.* 4.

Incomplete, but apparently articulated skeleton buried in the contracted position on the left side facing north. Only the skull, mandible, and incomplete long bones were preserved. The skull lay face downwards. The femora lay parallel and touching with the tibiae to the east, also parallel to one another. The left humerus lay south of the skull with the right humerus between the latter and the femora. An oval stone platter, which is shown in fig. 12, No. 8, was found in an inverted position to the south-east, at a slightly higher level than the body. This lay on the beach material, at a depth of 2¼ feet from the surface and had not been placed in a grave. The covering stones did not include the usual flat slab, all being less than 1¼ feet in length or breadth and appeared to have been disturbed. The inverted position of the stone platter and the absence of the usual covering slab suggest disturbance, and it is possible that the construction of the adjacent Iron Age hut C was responsible for stone robbery in this area.

H.H. 37 (*Cutting Is*). (Not illustrated.)

Very incomplete skeleton represented by the shafts of the femora and tibiae, one humerus, radius and ulna, fragments of the fibulae, scapulae and clavicles, together with some small pieces of skull and the teeth. All the bones had been extensively gnawed by rodents. The positions of the remains suggest that the skeleton was articulated when buried and that it was probably placed on the left side in a contracted position with the skull to the south-east. It lay on the beach material at a depth of 2½ feet from the surface, and was covered by some 9 inches of soil over which had been placed a rock slab 2½ feet long and 2 feet wide. No grave goods were found.

H.H. 38 (*Cutting IIs*), *Pl. XIV, No.* 6.

Articulated skeleton buried in the contracted position on the left side facing west. The right femur and tibia lay on those of the left leg. The left arm was flexed and lay to the east of the body, whilst the right was fully extended with the radius and ulna passing between the knees. A stone platter, shown in fig. 12, No. 5, was found on the circumference of the grave, behind the body and tilted towards it.

The remains lay in a shallow depression in the beach material and were covered by 1·5 feet of sandy soil over which had been placed a rock slab 3½ feet long and 3 feet wide. This is shown in section in Pl. XIV, No. 5.

7. Burial Mound E.

The small stone-covered burial mound which was situated at a distance of approximtely 160 feet E.S.E. of Cutting VIII proved to be similar in plan to those already described in the main cemetery but structurally better preserved. In common with the cemetery, it was found to overlie part of the occupation level, although this proved less rich in cultural remains than some of the areas previously excavated.

The mound was marked out for excavation into two cuttings 8 feet wide (north to south) by 16 feet long (east to west), forming a 16-foot square which enclosed the whole mound. The stones were plotted as successive layers were uncovered and the median east–west section was revealed. This is shown, together with the plan of the mound, in fig. 11.

In the centre of the mound a grave was found which had been dug into a stony scree to a depth of approximately 9 inches. It contained a dual interment accompanied by an oval stone platter * and two small beads. The stony structure covering the grave extended over a roughly circular area

* For convenience, the stone platter is described with those from the main cemetery on p. 330. The description of the beads will be found on p. 367.

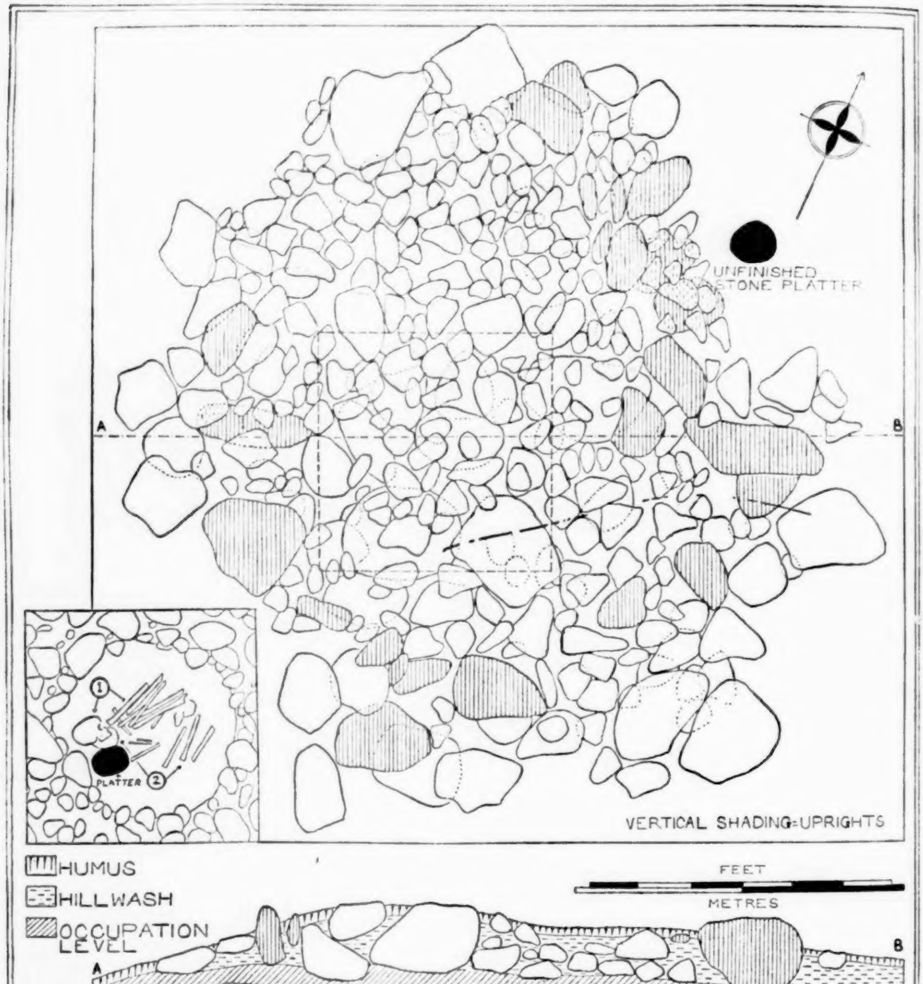
UNFINISHED
STONE PLATTER
A
B
1
2
PLATTER
VERTICAL SHADING=UPRIGHTS
HUMUS
HILLWASH
OCCUPATION
LEVEL
FEET
METRES
SCREE
HYRAX HILL. NAKURU. KENYA.
PLAN & SECTION OF BURIAL MOUND "E"
INSET: GRAVE WITH DUAL BURIAL

Fig. 11.

some 15 feet in diameter and was 1 to 1½ feet deep in the centre. As may be seen from the plan, a series of upright stones was found partly encircling the mound. Although only 24 of these had remained in position, it seems probable that the line was originally continuous and formed a complete ring.

The Skeletons.

Both the skeletons in the grave were in contracted positions. No. 1, the uppermost, lay on the left side facing north, with the knees drawn up towards the chin. Remains of one radius and ulna were found north of the body, the arm having been flexed, with the humerus lying beneath the left knee. The skull lay almost face downwards, and immediately behind it was found the stone platter shown in fig. 12, No. 12.

The second individual, which was presumably the primary burial, had been placed on the right side facing south-east. The skull lay immediately beneath that of No. 1 and was in a very fragmentary condition, as were the limb bones, although considerably more massive than those of No. 1. The femora lay parallel, with the knees over 1 foot distant from the facial region of the skull. (It should be mentioned that this is the only case of a burial on the right side, all those in the main cemetery having been placed on the left side, male and female alike.)

Both skeletons appeared to have been buried in an articulated condition. From the evidence supplied by the examination of the skeletons, it would seem that the platter was associated with skeleton No. 2, probably a female.

It is impossible to state with certainty whether the double interment took place simultaneously or whether the mound was reopened in order to receive the remains of the second individual some years after the first had been buried. But, since the remains of No. 2, although more massive, were in a markedly worse state of preservation than those of No. 1, and since the overlying stony structure of the mound did not appear to be so closely packed as was usual in the cemetery, it seems likely that the uppermost individual was buried at a somewhat later date than the first.

Objects Recovered from the Occupation Level.

The implements recovered from the area excavated are entirely similar to those already described, and it will suffice to append the numbers of each tool type which were found:

Crescents	3	Micro-burins	0
Fragments of crescents	2	Burins	0
Borers	0	Burin spalls	1
Obliquely trimmed points	0	Scrapers (end)	7
Backed blades	2	Hollow scrapers	2

Lames écaillées	5	Cores	6
Blades	2	*Waste Material.*	
"Sinew frayers"	0	Whole and bulb ends of flakes	145
Utilised flakes, triangular	6	Distal fragments	321
Utilised flakes, various	36		

In addition to the foregoing implements and waste flakes, three potsherds were recovered which, although undecorated, clearly belong within the range of sherds from the main site. Two are of a brownish-buff ware, well-fired and well-gritted. They are obviously derived from the same vessel. The third sherd is reddish buff on the exterior and black on the interior, it is ill-fired and very brittle. Five small chalcedony pebbles, similar to those already mentioned, were also found, together with an unfinished stone platter which is shown in Pl. XVI, No. 1 and fig. 12, No. 13. This is of particular interest in view of the method of manufacture exhibited, which differs somewhat from that displayed in the unfinished stone bowl recovered from the Nakuru Burial Site in 1926.

The unfinished platter from Mound E shows clearly defined tool marks in the central area, which has been hollowed out to a depth of approximately half an inch. No tool marks are visible on the circumference of this area which would eventually form the rim of the finished vessel, nor on the exterior which appears to have been only crudely dressed. In the roughly horizontal centre of the tooled area the marks exhibited are pecks or pittings, approximately 8 mm. in diameter, and appear to have been caused by a pointed instrument. Those on the sloping edge, however, are overlapping flat chisellings, the widest measuring 0·8 inch in breadth.

The description given for the Gumban B unfinished vessel is as follows: "The softer pumiceous lava has been picked in the form of a circular trench round a central core. One presumes that when the trench was a little deeper the central core would be struck a blow in order to detach it and the excavation would then continue" (8).

That some such method would be the most convenient for the manufacture of the deep bowls and basins of the Gumban B Variant of the Stone Bowl Culture is obvious. For the shallow stone platters, on the other hand, the hollowing out of the interior would be a comparatively simple task and little would be gained by leaving a central core. Moreover, on account of the relatively greater diameter such a method would not be practicable.

8. The Grave Goods from the Cemetery and Mound E.

The Stone Platters.

Nine complete stone vessels were recovered from the graves, together with five fragments from the occupation level, these, although not classed

as grave goods, are described with the complete specimens from the cemetery for convenience sake.

Stone platters appear to have been placed only in female interments. The examination of the skeletal material has revealed that all comparatively well-preserved individuals buried with stone platters were female. Nor is there any suggestion to the contrary among those which are very fragmentary and consequently impossible to sex with certainty. On this evidence it seems that stone platters must be regarded as typical grave goods of the female interments in the Hyrax Hill cemetery.

The vessels are of an entirely flat, shallow form, best described as a platter in order to distinguish the type from the deeper bowls and basins of the Gumban B and other branches of the East African Stone Bowl Culture. The rocks from which the platters are made are invariably of local origin and consist of consolidated and laminated tuffs which occur in the immediate vicinity of Hyrax Hill.

Circular, oval, and slightly elongate forms are represented in the series, the first predominating, with 7 examples. It will be seen from the description of the illustrated specimens that the internal depth of the platters ranges from 0·8 to 1·9 inches and the maximum diameter from 8 to 11·4 inches. The calculated diameter of 2·4 inches for the very small fragmentary specimen from the occupation level is considerably lower than any of the complete specimens. No example exceeds 3·2 inches in height.

The workmanship exhibited varies considerably. No. 1, fig. 12, is a highly finished product showing a well-defined rim and careful smoothing of both interior and exterior surfaces. In contrast, No. 9, fig. 12, is extremely crude and although the material may be in part responsible for the roughness of the vessel, no attempt seems to have been made to achieve symmetry.

The traces of burning which are present on two of the platters from the cemetery and on the oval platter from Mound E should be noted. This feature is particularly in evidence among the stone bowls recovered from the Njoro River Cave and is fairly common in other branches of the Stone Bowl culture. These vessels from the Njoro River Cave exhibit intensive burning and blackening of the interior surface, which in some examples extends throughout the thickness of the base and may be taken to indicate that fire or embers were present in the vessels for a considerable period of time. The Hyrax Hill platters, however, show merely traces of superficial firing such as might be caused by the burning of food offerings in the vessels during funerary ceremonies.

In three graves a combined pestle-rubbing stone was found beside the skeleton, in addition to the stone platter. This association suggests that the platters may have been employed as mortars for crushing wild roots

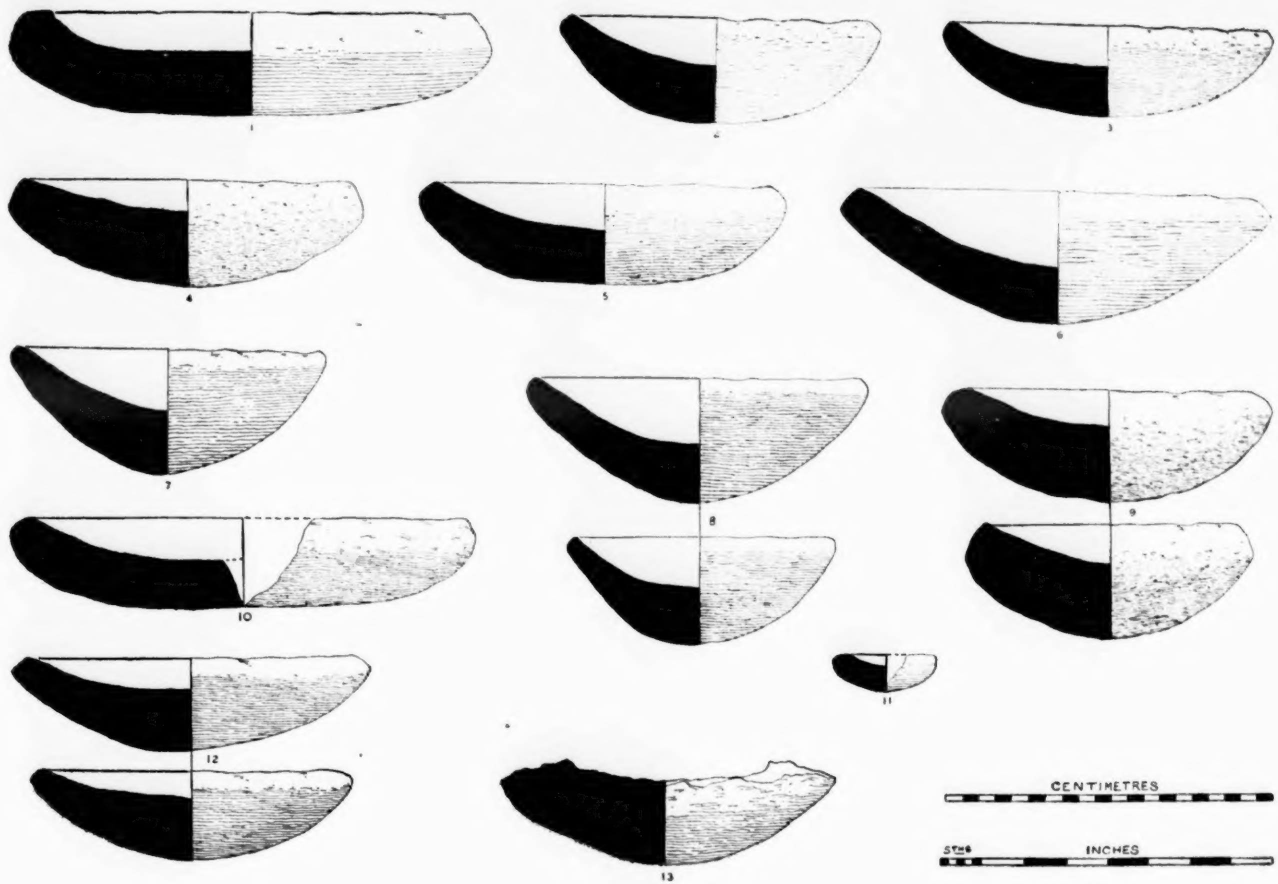

FIG. 12.—The Stone Platters.

No. 1. Complete, well-made stone platter.
Material: consolidated tuff.
Maximum external diameter: 11·4 inches } 1 inch below the rim apex.
Minimum „ „ : 10·8 „ }
External height: 2·4 inches.
Internal depth : 1·5 „
From Cutting IV. Buried with Skeleton No. 21. Catalogue number S. 12.

No. 2. Stone platter. Some 8 inches of rim circumference preserved.
Material: consolidated tuff.
Maximum external diameter: 8 inches. } 0·4 inch below the rim apex.
Minimum „ „ : 7·7 „ }
External height: 2·5 inches.
Internal depth : 1·2 „
From Cutting I. Buried with Skeleton No. 11. Catalogue number S. 7.

No. 3. Stone platter. Approximately two-thirds preserved.
Material: laminated tuff.
External diameter: *c.* 8 inches. (0·5 inch below the rim apex.)
External height: 2·2 inches.
Internal depth : 0·9 „
From Cutting I. Buried with Skeleton No. 10. Catalogue number S. 3.

No. 4. Complete, crude stone platter.
Material: laminated tuff.
Maximum external diameter: 8·7 inches } 1 inch below the rim apex.
Minimum „ „ : 8·2 „ }
External height: 2·5 inches.
Internal depth : 0·8 „
From Cutting VII. Buried with Skeleton No. 32. Catalogue number S. 20.

No. 5. Complete stone platter showing traces of burning on the interior surface.
Material: consolidated tuff.
Maximum external diameter: 8·7 inches } 0·8 inch below the rim apex.
Minimum „ „ : 7·9 „ }
External height: 2·4 inches.
Internal depth : 1·1 „
From Cutting IIB. Buried with Skeleton No. 38. Catalogue number S. 27.

No. 6. Complete, well-made stone platter.
Material: consolidated tuff.
Maximum external diameter: 10·7 inches.
Minimum „ „ : 10·3 „
External height: 3·2 inches.
Internal depth : 1·9 „
From Cutting Ix. Buried with Skeleton No. 1. Catalogue number S. 1.

No. 7. Complete stone platter.
Material: laminated tuff.
Maximum external diameter: 8·2 inches } 0·3 inch below the rim apex.
Minimum „ „ : 7·9 „ }
External height: 3·1 inches.
Internal depth : 1·4 „
From Cutting IV. Buried with Skeleton No. 22. Catalogue number: S. 28.

No. 8. Complete oval stone platter showing traces of burning on the interior surface.
Material: crystal tuff.

and seeds or possibly grain, although there is no indication at present of contemporary agriculture in East Africa.

The fact that only three out of the nine graves in which stone platters were found also contained pestles may be due to the fact that these were made of basement complex rocks, the nearest outcrop of which lies at a distance of over 50 miles from Hyrax Hill. The pestles may therefore have been considered of more value than the platters, which, being made of local rocks, could easily be replaced.

Among the five fragments of stone platters recovered from the occupation level only two need be mentioned, namely, the fragment of a particularly flat vessel shown in fig. 12, No. 10, which bears a very close resemblance to

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Maximum external diameter: 8·3 inches } 0·4 inch below the rim apex.
Minimum ,, ,, : 6·5 ,, }
External height: 3 inches.
Internal depth: 1·5 ,,
From Cutting IIIb. Buried with Skeleton No. 36. Catalogue number S. 21.

No. 9. Complete oval stone platter.
Material: consolidated tuff.
Maximum external diameter: 8·1 inches } 0·5 to 0·7 inch below the rim apex.
Minimum ,, ,, : 6·8 ,, }
External height: 2·8 inches.
Internal depth : 1 inch.
From Cutting IV. Buried with Skeleton No. 23. Catalogue number S. 14.

No. 10. Two fragments of a stone platter.
Material: vesicular lava.
Approximate diameter: 11 inches.
,, external height: 2·1 inches.
,, internal depth : 0·5 ,,
From Cutting Is, layer 2. Catalogue number S. 25.

No. 11. Fragment of a small stone vessel.
Material: consolidated ash.
Approximate diameter: 2·4 inches (0·3 inch below the rim apex.)
,, external height: 0·9 inches.
,, internal depth : 0·5 ,,
From Cutting II, layer 2. Catalogue number S. 29.

No. 12. Complete oval stone platter, the interior surface showing signs of intensive burning.
Material: laminated tuff.
Maximum external diameter: 8·7 inches } 0·5 inch below the rim apex.
Minimum ,, ,, : 7·7 ,, }
External height: 2·2 inches.
Internal depth : 0·8 ,,
From Mound E. Buried with Skeletons Nos. 1 and 2. Catalogue number S. 3.

No. 13. Unfinished stone platter.
Material: laminated tuff.
Maximum external diameter: 8 inches.
Maximum external height : 2·6 ,,
From Mound E. Catalogue number S. 22.

the complete stone platter S. 12 illustrated in the same figure, although not so well made, and the fragment of an unusually small stone vessel shown in No. 11 of the same figure. Although comparatively rare, such small stone vessels are not unknown in the East African Stone Bowl Culture. Amongst others, several examples have recently been found on the Kinangop Plateau, apparently associated with two ground stone axes of the bossed type.

Although a paper is now being prepared by Mrs. B. E. B. Fagg on the distribution of the East African stone bowls which will also furnish data on the types found in association with different Neolithic industries, it may be of value to give some short notes in the present paper concerning the stone platters previously discovered, which are comparable to those from the Hyrax Hill cemetery.

The platter appears to be a somewhat rare type of stone vessel, since, in addition to the Hyrax Hill series, only five unquestionable specimens are known out of a total of 160 stone vessels from Kenya and Tanganyika Territory. Four of these were obtained during excavations and it is therefore possible to determine the industry to which they belong. Although only the five true platters are known, it should be mentioned that among the stone bowls recovered from the Nakuru Burial Site and the Njoro River Cave, there are a number of shallow basins approaching the deeper of the Hyrax Hill specimens, but in every case somewhat more bowl-like and with better defined rims.

The first of the five platters mentioned above was discovered by the East African Archaeological Expedition during 1929 in a small burial mound near the Gilgil River, Naivasha. With it were found a number of obsidian crescents and a large pottery jar measuring 29 inches in height. This is round bottomed with a slight neck, and has a decoration just below the rim consisting of three horizontal lines formed by series of small vertical lozenge impressions. The burial in which these objects were found appears to be entirely similar to those excavated at the Makalia Burial Site and may be attributed to the Gumban A Variant of the Stone Bowl Culture.

In 1929 Mr. T. Powys Cobb and Mrs. Creasy, who were members of the East African Archaeological Expedition, opened a grave at the Old Government Farm, Naivasha, which appears to have been of the Gumban A type. In it were found a badly preserved female skeleton and a stone platter. There were no other grave goods and nothing apart from the method of burial to indicate the culture to which the grave belonged, but the pottery on the surface resembled that from the Makalia Burial Site.

During the excavation of the Njoro River Cave in 1938 a single platter was found out of a total of ninety stone bowls and basins. The vast amount of material recovered from this site, including obsidian implements, pottery,

burned fabrics, skeletal material and numbers of beads made from semi-precious stones, has yet to be studied. From observation in the field, however, it seems clear that the culture as a whole is dissimilar from any hitherto discovered in Kenya, although certain elements, in particular the obsidian implements, suggest affinities to the Elmenteitan and possibly to the Gumban B Variant of the Stone Bowl Culture.

The stone platter recovered from the Naivasha Burial Site in 1940 also proved to be the only specimen of its kind in a series of eight stone bowls. The culture represented at this site does not appear to be closely comparable to that of the Njoro River Cave since certain features were missing. It does, however, provide some points of similarity and must be provisionally assigned to that group of the Kenya Neolithic.

Half a stone platter was found on the surface of the ground in a part of the Naivasha Railway Rockshelter before the excavation of the site in 1940. Since nothing was found in association, this specimen is unfortunately of little value.

From the above notes it will be seen that although occasional platters occur within certain series of stone bowls, the type is rare and never constant as in the Hyrax Hill group. It is regrettable that only two specimens are known from Gumban A sites, since the many elements common to that and to the Hyrax Hill Variant of the Stone Bowl Culture suggest that in the Gumban A all the stone vessels might well prove to be of the platter type.

Note on the Occurrence of Stone Bowls in the Sudan.

The only examples of similar stone bowls which I have been able to trace outside East Africa are from the Sudan. These bowls are still being made to-day although they are rapidly becoming obsolete through the introduction of aluminium saucepans. One specimen has been sent to the Nairobi Museum through the kindness of Mr. A. J. Arkell, Commissioner for Archaeology in the Sudan. This bowl, or rather shallow basin, measures *circa* 9 inches in diameter at the rim and is $3\frac{3}{4}$ inches high. It is considerably more asymmetrical than the majority of those found in Kenya. Four rudimentary handles or lugs are carved on the outside of the rim, but it appears that simple bowls without such handles are also made and that these are largely for ornamental purposes.

Mr. Arkell informs me that not long ago stone bowls were made in large numbers for sale in the Kareima market, but are now only made to order. They are used for cooking and, although food cooked in these vessels takes longer to heat, they endure repeated firing very much better than pots.

The Pestles.

Five pestles or pounders were found, three of which were recovered from graves where they were associated with stone platters, the other two specimens being from the occupation level.

These implements are all manufactured from basement complex rocks, quartzes and gneiss, none of which occur in the vicinity of Hyrax Hill.*

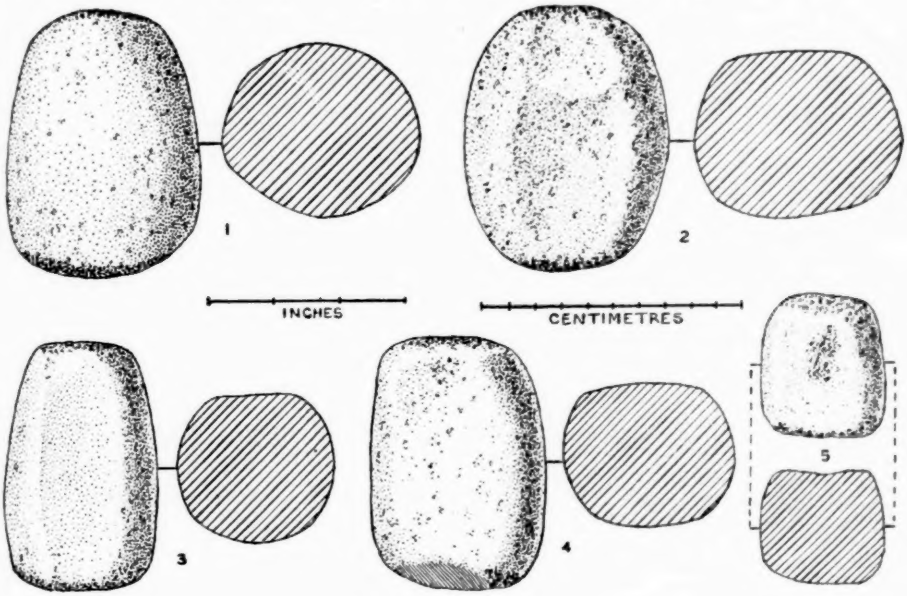

Fig. 13.—The Pestles.

No. 1. Pestle-rubber. Material: basement complex quartz.
Maximum length: 4 inches.
Maximum median diameter (lateral): 3 inches.
Minimum ,, ,, : 2·6 ,,
The narrow extremity of the implement shows heavy bruising whilst the broad extremity, although bruised on the circumference, shows a rubbed surface which appears to have been caused subsequent to the bruising.
From Cutting I. Buried with Skeleton No. 11. Catalogue number S. 5.

No. 2. Pestle-rubber. Material: schistose-quartzite (?).
Maximum length: 4·1 inches.

* The outcrops of basement complex rocks refered to above occur at the Amala River Sotik, at Nanyuki, and in the Baringo region. Owing to the fact that the quartzes from these areas are very similar and that no knowledge exists of differential characters, I have not submitted the pestles to mineralogical tests, since this would serve no useful purpose.

The five examples differ considerably in form, No. 1, fig. 13, being elongate and oval sectioned, while No. 5 of the same figure is rectangular, all, however, show one or more bruised areas, either at the extremities or on the upper or lower faces of the implements. Evidence of careful shaping, in order to obtain the required form, is also present with the possible exception of No. 1, fig. 13, in which the utilised areas at the extremities are a light yellowish-white colour in contrast to the reddish-brown surface on the body of the implement. This may indicate that a natural quartz pebble was used, being worn down at the extremities only.

Bruised or pecked areas such as those seen on the small rectangular pestle No. 5 are also found in the pestles and rubbers of the Gumban B Variant of the Stone Bowl Culture, although in these the hollows are considerably more pronounced.

It should be mentioned that pestles, generally made from basement complex rocks, are found in nearly all the Neolithic cultures of Kenya, particularly in the different branches of the Stone Bowl Culture. A large number were recovered from the Njoro River Cave in which a variety of types are represented. When this series is studied, it may be possible

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Maximum median diameter (lateral); 2·1 inches.
Minimum ,, ,, : 2·55 ,,
Both extremities are bruised and two intersecting rubbed planes are present both on the upper surface shown in the figure and on the obverse.
From Cutting V, layer 2. Catalogue number S. 15.

No. 3. Pestle-rubber. Material: Garnet Gneiss.
Maximum length: 3·7 inches.
Maximum median diameter (lateral: 2·4 inches.
Minimum ,, ,, : 2·2 ,,
Both extremities show bruising and the surface shown in the figure has been utilised for rubbing.
From Cutting Ix. Buried with Skeleton No. 1. Catalogue number S. 2.

No. 4. Pestle-rubber. Material: basement complex quartz.
Maximum length: 3·8 inches.
Maximum median diameter (lateral); 2·6 inches.
Minimum ,, ,, : 2·2 ,,
An oblique, very smooth rubbed area is present on either extremity, truncating the bruised surfaces and caused subsequent to the latter.
From Cutting Is, layer 2. Catalogue number S. 24.

No. 5. Pestle. Material: basement complex quartz.
Maximum length: 2·2 inches.
Maximum median diameter (lateral): 1·8 inches.
Minimum ,, ,, : 1·7 ,,
Intensive bruising is present on both extremities, whilst the ventral, dorsal, and both lateral surfaces show a pecked or bruised area. This is most marked on the figured surface where it forms a slight hollow.
From Cutting Iv. Buried with Skeleton No. 23. Catalogue number S. 13.

to make a classification and define certain types. At present, however, it seems that no one type was confined to any particular culture and comparisons are therefore valueless.

Note.—The four beads recovered from the grave of Skeleton H.H. 21 and from Mound E are described on p. 367 and illustrated in Pl. XXII, together with the other beads recovered during the excavations.

The Stone Basins Recovered from the Hillwash Overlying the Neolithic Level at Site I.

Nine fragments representing three stone basins were recovered from the upper part of the brown hillwash (layer 1), which overlay the neolithic occupation level and cemetery at Site I. Eight of these were from Cuttings II, III, and V, whilst one fragment fitting those from Cutting III was found some 170 feet distant in a trial trench excavated below the floor level of the Iron Age Hut E.

The type of stone basin to which these fragments belong is characterised by a narrow, sharp rim, slightly incurved on the exterior and in which the maximum diameter is situated 1 to 1½ inches below the lip. The base, which is preserved in one vessel, tends to be flat. The workmanship exhibited in all the fragments is good, both interior and exterior surfaces being well finished and smooth, whilst the rims are regular and of an even thickness. It can be said that the basins show a considerably higher standard of workmanship than the platters from the underlying level.

No. 1, fig. 14, from Cutting II, consists of three fragments of rim, the base not being preserved. A total of 7·3 inches of the rim circumference is present, giving an approximace diameter of 7 inches. The material is consolidated tuff and the catalogue number S. 4.

No. 2, fig. 14, from Cutting III and the Trial Trench in Hut E, represents over three-quarters of the vessel, which is also made from consolidated tuff. The measurements are as follows:—

Diameter of rim . .	7·1 inches.	
Maximum diameter (1·3 inches below the lip of the rim) . . .	7·7 ,,	
External height . .	3·5 ,,	
Internal depth . . .	3 ,,	(Cat. Nos. S. 30 and S. 34.)

The two fragments of a third basin, in which only 3 inches of the rim circumference is preserved, are not figured, but clearly belong to the same type as the two described above.

A few scattered obsidian implements and flakes were also found in the hillwash which are not sufficiently numerous to be assigned to any particular industry.

The type of stone basin described above is known from the Gumban B Nakuru Burial Site; from the Njoro River Cave, and from various isolated

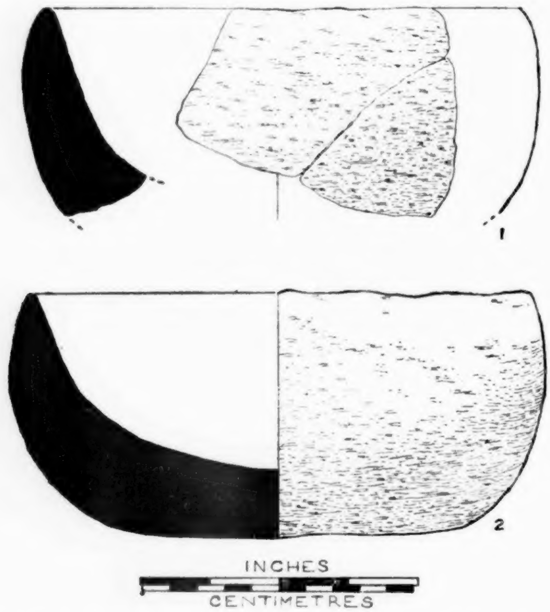


Fig. 14.—Two Stone Basins from the hillwash overlying the Neolithic occupation level.

surface finds in the Rift Valley. The occurrence of such basins in the upper part of the hillwash therefore provides some indications as to the period at which this was deposited, namely, during the time when the Gumban B Variant of the Stone Bowl Culture existed in the neighbourhood of Hyrax Hill. This Variant, on the evidence obtained from the excavation of the Nakuru Burial Site, has been correlated with the Nakuran Wet Phase and provisionally dated *circa* 850 B.C.

PART II.

The Iron Age Settlement.

The dry stone walls of the enclosures and hut circles belonging to this settlement were found to have been built on the deposit of brown hillwash in which the stone basins of Gumban B type were found.

Associated with the stone enclosures were nine shallow burial pits containing the remains of approximately nineteen individuals. Examination of these remains has revealed that with the exception of one child's skeleton, all are males, mostly young adults. A number had undoubtedly been decapitated and from the positions of the limb bones in the pits there is reason to suppose that a proportion were also dismembered.

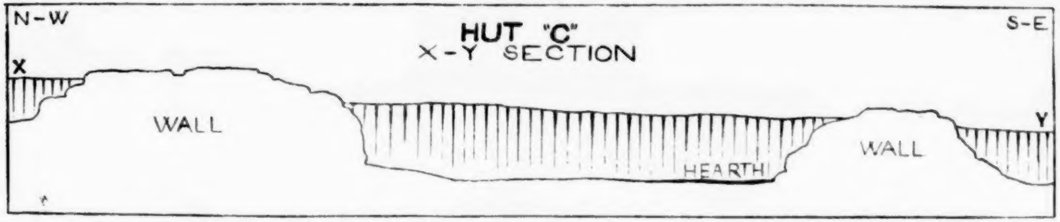
Little or no humus covered the site, suggesting that it must be of comparatively recent date. This is further borne out by the objects recovered from the enclosures, which include glass beads, iron objects, cowrie shells, and pottery pipe bowls. All of these, in particular the pipe bowls, which appear to belong to water-pipes, indicate that trade contact with the coast was already established at the time the settlement was occupied.

It seems clear, however, that the settlement was neither built nor occupied by members of the nomadic Masai tribe who inhabited the Nakuru region prior to the arrival of the Europeans during the nineteenth century. The dwellings of these people are of an extremely temporary nature and never involve the use of stone. Furthermore, no beads or other cultural objects which can definitely be associated with the Masai were found during the excavations.

The fact that no water is to be found within reasonable distance of the site under present-day climatic conditions suggests that the settlement may have been occupied during a short wet spell; sufficient, perhaps, to form semi-permanent pools and marshes in the flats nearby.

The walls of the enclosures were clearly visible before excavation, standing in places 3 feet above present ground level. They comprised two adjacent horseshoe-shaped kraals measuring respectively 40 and 60 feet across and considerably more in length, divided by a common wall. These enclosures lay backed against the hill in a small bay and faced out, overlooking the plains in a south-easterly direction (see Plan I). Abutting on the two outer walls, both on the interior and exterior of the enclosures, occurred a number of subsidiary structures, forming small hut circles. One of these, Hut A, was excavated, but with negligible results.

At the entrance of the larger of the two kraals (Enclosure C), a rubbish mound or midden was found, which, in certain areas, contained a number of small hearths together with a considerable quantity of broken animal


HUT "C"
X-Y SECTION
N-W
S-E
X
Y
WALL
WALL
HEARTH

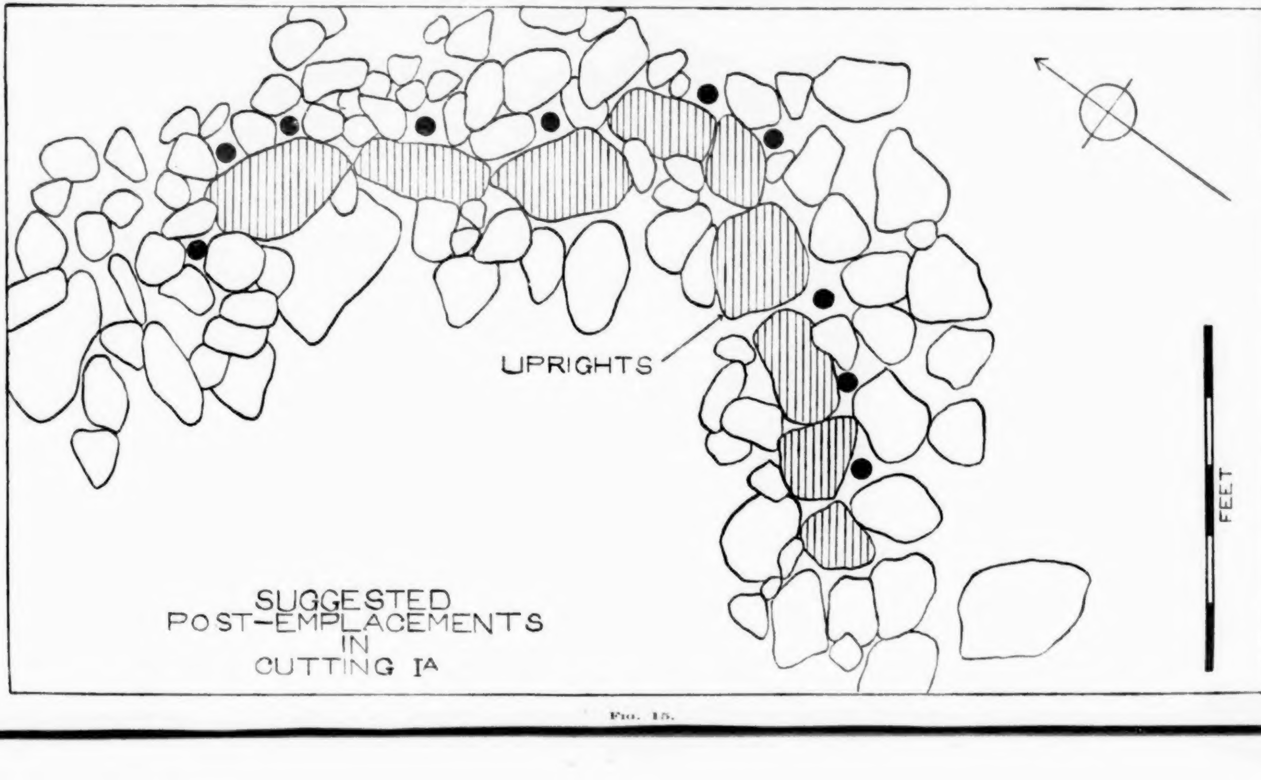

UPRIGHTS
FEET
SUGGESTED
POST-EMPLACEMENTS
IN
CUTTING IA

FIG. 15.

bones, potsherds, fragments of pottery pipe bowls, iron objects, beads, and bone pendants.

In front of the entrances of Enclosures B and C lay a pair of small isolated hut circles, one of which (Hut C) was excavated. From their position it seems likely that these may have constituted guard-houses.

The walls of all the enclosures proved to be loosely built of small boulders and stone derived from the slope of the hill. No trace of dressed blocks or any form of mortar was found. It should be mentioned that the amount of fallen stone taken in conjunction with the present height of the walls above floor level appeared to be inadequate for walls which would permit standing room within the smaller hut circles, if these were ever roofed. It seems likely, therefore, that some perishable superstructure was employed, possibly wood or hides stretched on poles, and that the stone walls were in fact nothing more than foundations. The indications of post emplacements found in Cutting Ia tend to support this view (see fig. 15).

Outside the entrance of Enclosure B eight burial pits were found, containing the remains of multiple interments, which, in some cases, appeared to have been both decapitated and dismembered. The largest of these pits (A3), in Cuttings III and IV, contained the remains of at least six persons. A further pit, A8, was found in Cutting IIIc, lying adjacent to the eastern guard house. Only a small number of cultural objects were recovered from the pits. These consisted of two iron rings and an iron bracelet with Skeleton H.H. 20 in Pit A5 and a few potsherds similar to those found in the enclosures, in the other pits.

1. The Excavations.

Enclosure B.

A trial cutting 10 by 10 feet was made within the enclosure. A floor level of undisturbed pumice material was found at a depth of 0·7 to 1 foot from the surface. The only finds were two undecorated potsherds.

Hut A.

The interior and entrance of the elongate Hut A were next cleared. The interior measured approximately 21 feet in length and 11 feet in width. A trampled earth floor was found at an average depth of 9 inches from the surface. The inner face of the north wall, which was considerably higher and more massive than the south wall which lay within Enclosure B, was found to have been lined at the base with a series of large upright slabs. The entrance, at the eastern end of the hut, was exceedingly narrow and

measured only one foot across. On either side, in the position of gate-posts, a large boulder was found; that on the south apparently an *in situ* block incorporated in the wall. Beyond these two boulders, which stood at the narrowest point of the entrance, a slightly wider outer passage or porch was found. This was approximately 10 feet in length. No hearth was found within the hut and the filling contained only 16 potsherds, four of which show impressed cord decoration, some broken animal bones and teeth, and a fragment of schist rubbing stone.

A trial cutting 22 feet long and 10 feet wide was made north of the entrance of Hut A where a small isolated pile of stones was observed. The purpose of these stones was, however, not discovered, and the cutting yielded only some 10 potsherds and a few fragments of animal bones.

Hut C.

The western guard-house, which lay outside the entrance of Enclosure C, was excavated by means of two cuttings each 15 feet long and 9 and 11 feet wide respectively. A median section through the hut was thus revealed. The walls stood 6 to 9 inches above ground level before excavation. When the filling was removed, they were found to stand 1 to 1½ feet above the floor level and to be 4 feet wide at the base. The entrance lay to the south and the interior measured 5 to 6 feet in diameter. An earth hearth was found immediately inside the entrance, on the southern side. No hearth stones were discovered, and it was noticeable merely as a small circular area of burned red soil with traces of ash and charcoal. Outside the entrance a pair of small boulders were found in the position of gate-posts.

The objects recovered from the hut include one fragment of human infant's skull and 23 potsherds, six of which exhibit impressed cord decoration. A few sherds were also found in the excavated area outside the hut.

Enclosure C and the Midden.

Ten cuttings, each 10 feet wide and varying from 15 to 20 feet in length, were made within Enclosure C and through the midden which lay at the entrance. A well-defined floor level was found in all the cuttings, which, in certain areas, consisted merely of trampled earth, but more commonly of close packed stones forming a cobbled surface. This was particularly noticeable in Cutting Ij and Im. The presence of innumerable rodent burrows had considerably damaged the surface of the floor and rendered it impossible to determine whether any post holes had existed.

The midden attained maximum thickness in Cuttings If, Ig, and Im, where it reached a height of approximately 1·6 feet. In these cuttings a

number of small hearths also occurred. These were roughly circular in shape and measured 1 to 1·6 feet in diameter. As in the hearth found in Hut C, no hearth stones had been used and the hearths consisted merely of consolidated ash and charcoal, about 6 inches in thickness and burned either red or grey.

In cuttings Ij, Ik, and In, the midden was not present and the remains of the occupation were recovered from the 6 to 9 inches of surface soil which overlay the floor level.

The south-east extremity of the common wall dividing Enclosures B and C curved to the south in Cutting Ia, forming a small incomplete enclosure or hut circle (see fig. 15). In this, a series of nine upright stones were found placed end to end lengthwise in the centre of the wall. On the outer side it was noticed that groups of small stones had been piled and wedged against the uprights, forming gaps 4 to 6 inches in diameter and spaced at intervals of 0·9 to 2 feet. This structure, although necessarily somewhat irregular owing to the nature of the stones employed, appeared to be intentional and may, perhaps, represent post holes intended for the support of the roof or upper wall of the hut. If this was the case, the upright stones would presumably be intended to prevent the posts falling inwards by supplying firm supports on the inner side. Although indications of this structural feature were observed elsewhere they were not sufficiently well preserved or clearly defined to be of any value and the interpretation given above must therefore be regarded as tentative.

In addition to the cultural remains from the areas described above, a number of scattered potsherds, animal bones and other cultural objects were discovered in the top soil of all the cuttings made through the Neolithic cemetery and occupation level at Site I.

2. The Pottery.

Some 1497 potsherds were found. These were scattered throughout the excavated area but were more abundant in the midden, which lay at the entrance of Enclosure C. Eleven or twelve vessels may be distinguished among the sherds, on the basis of rim types and decoration. Owing to the great similarity in thickness and type of wares, these cannot be used as criteria for differentiating vessels.

Although the number of sherds is in excess of that recovered from the Neolithic level, in which 28 vessels are represented, the fragments are noticeably smaller and it is obvious that fewer pots are represented. None are sufficiently complete to render reconstruction possible, and in only three cases is enough of the rim circumference preserved for the diameter of the mouth to be calculated with any exactitude.

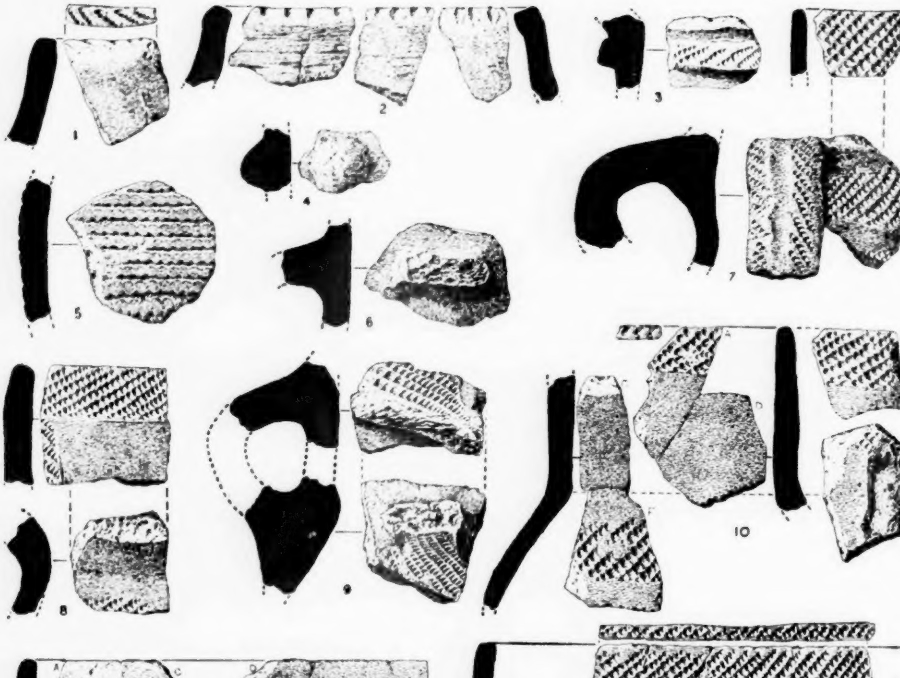


FIG. 16.—Sherds from the Iron Age Level at Site I.

(1) Rim sherd of gritty red ware showing five hyphenated cord impressions on the upper surface. From Cutting Ig (P. 487).

(2) Four rim sherds probably belonging to one vessel, showing a decoration of vertical notches on the external angle of the rim. From Cuttings Ia, Il, IIc (P. 45, 662, 868, 932).

(3) Fragment of black ware showing a raised horizontal band with impressed cord decoration. From Cutting IIIb (P. 1930).

(4) Small applied boss or knob on sherd of black surfaced ware with red-grey core. From Cutting If (P. 389).

(5) Sherd of black ware with impressed fabric (?) decoration forming conjoined circles in parallel rows. From Cutting VIII (P. 1490).

(6) Fragment of undecorated handle. Red ware. The interior is unusually rough. From Cutting III, Ext. N (P. 1161).

(7) Rim, wall and two handle sherds of a vessel showing impressed cord decoration applied in two horizontal zones, together with a double vertical band upon the handle. Traces of a third horizontal zone are also visible on the shoulder. Red, gritty-surfaced ware with grey core. Rim sherd from Cutting Ih (P. 577); handle sherds from Cutting Il (P. 385, 391); wall sherd from Cutting In (P. 767).

(8) Rim and neck sherds of vessel showing corded decoration in two horizontal and one vertical band. The ware is black on the exterior surface with a grey-black core, fired red on the interior. Rim sherd from Cutting IIIc (P. 102); neck sherd from Cutting If (P. 637).

(9) Two fragments of a large handle decorated with a single broad band of cord impressions. Gritty ware with grey-black core, fired reddish black on the exterior. From Cuttings If (P. 388) and In (P. 766).

(10) Six sherds of a necked vessel showing cord decoration and a handle emplacement. The decoration is present in two horizontal zones, beneath the rim, on the shoulder, and on the upper surface of the rim. The handle sherd further suggests that vertical bands may also have been present. The ware is grey cored, fired red on the exterior; three sherds show subsequent blackening of both surfaces. Sherds A, C, E, F from Cutting IIIb (P. 1929, 1947, 1927, 1959); Sherd B from Cutting IIc (P. 931); Sherd D from Cutting If (P. 407).

(11) Eight sherds of an undecorated straight rimmed vessel, showing traces of a shoulder. The fragments are variable in colour, those on the left being grey cored with light red or reddish-grey surfaces, whilst those to the right are black throughout. The calculated diameter for the mouth of this vessel is 8·1 inches. Sherds B, C, D, E from Cutting VII (P. 1510, 1581, 1487, 1515); Sherds A, F, G, H from Cutting VIII (P. 1595, -96, -97, -98).

(12) Five sherds of vessel showing corded decoration in a series of vertical bands and a single horizontal zone beneath the rim in addition to a double band on the shoulder. The upper surface of the rim is likewise decorated. The ware is red to reddish brown in colour throughout. The approximate diameter at the mouth being 4·1 inches. Shoulder sherd from Cutting IV, Ext. N (P. 1254); the remainder from Cutting Vs (P. 1905).

(13) Nine sherds of a necked vessel with two horizontal bands of corded decoration The sherds with the exception of A, F, which have become blackened through subsequent firing, are grey cored and light red on both surfaces, with the characteristic "sandpaper" texture, although evenly finished. It is probable that a fragmentary handle, not figured but similar to that shown in No. 7, belongs to this vessel. Sherds B, C, D, I from Cutting VII (P. 1438, 1513, 1552, 1493); Sherds

The Wares.—The wares vary considerably in colour although all are uniformly well fired with fine grits and evenly finished surfaces. These are, however, somewhat rough in texture and reminiscent of fine sandpaper, when the vessels have not been burnished. The core is generally black or grey, fired red to varying thicknesses on the exterior. A proportion of the sherds are black or grey throughout, but these are relatively scarce and seem to occur as localised areas within a vessel which otherwise exhibits the characteristic red-grey-red section. A grey or black burnished surface is present on some sherds. A proportion have also become blackened through use.

Evidence as to the technique of manufacture is lacking, but since no sherds exhibit horizontal concave-convex cleavages it may be concluded that the coil or ring technique, prevalent in the Neolithic level, was not used.

Form and Rim Types.—Little can be said regarding the form of the vessels owing to their fragmentary condition, but it may be concluded that a more or less pronounced neck was usually present, together with vertically applied handles which appear to have spanned the neck-shoulder angle. The eight rims recovered show little variation, all are straight and flat topped, differing in thickness only in accordance with the size of the vessels.

No complete base was recovered, but a number of basal fragments indicate that these were round, similar to those from the North-East Village.

Decoration.—A large number of the sherds exhibit bands of impressed cord decoration varying from half to three-quarters of an inch in width, and it seems that this motif was employed to the exclusion of nearly all others. The decoration is usually found below the rim. In two vessels this is combined with further diagonal coil impressions on the lip of the rim. Two rim sherds belonging to the same vessel exhibit merely these diagonal impressions without the usual horizontal band beneath the rim. When the shoulder of a vessel is preserved, a second horizontal band, either single or double, is found on the shoulder itself. In three cases vertical bands linking the upper and lower horizontal zones also occur.

The handles, which appear to have been placed vertically, likewise usually exhibit a single or double decorative band along their length which presumably continued to the rims of the vessels.

A, F, E from Cutting VIII (P. 1576, 1599, 1600); Sherds G, H from Cutting II (P. 1024, 224).

(14) Small handle showing a double band of impressed cord decoration on its length. Possibly belonging to the vessel represented in No. 12, being of the same reddish-brown ware. From Cutting IX (P. 380).

Four further types of decoration were found, one of which, a notching of the rim, is present only on four small sherds and may well have been combined with corded decoration on the body of the vessel. It should be mentioned that the notches are broader and more widely spaced than those of the "milled rim" vessels in the earlier cultures, in which, moreover, the notches extend on to the upper surface of the rim and are not confined to the external angle.

Eleven sherds were found which show an unusual type of "all-over" decoration, apparently caused by the impression of some coarse fabric. In these sherds the surface has been demarcated into parallel rows of small conjoined circular areas, interspaced by depressed, parallel wavy lines.

In addition to the above, one sherd was recovered which shows a raised horizontal band on which there are hyphenated cord impressions, together with one sherd having a small circular knob or boss. This, on account of its size, was presumably solely for decorative purposes.

Repair Holes.—Three sherds were recovered bearing drilled holes, which appear to have been rivet holes.*

3. The Pottery Pipe Bowls.

Remains of nine pottery pipe bowls were recovered. Some are so fragmentary that it is impossible to determine which form of pipe is represented. Only one example is nearly complete and even this lacks the base (No. 1, fig. 17). The preserved part, however, strongly suggests that it is a water-pipe bowl, since the hour-glass form is entirely characteristic of this type of pipe and the specimen is very similar to the older pottery pipe bowls from S. Africa which are known to have been used by the natives for this method of smoking (9).

Three of the other examples are decorated and three show considerable blackening of the interior. No. 6 of fig. 17 also appears to belong to the water-pipe form and it is probable that the remaining specimens were of the same type although insufficient is preserved for this to be stated positively.

The occurrence of pipe bowls and in particular of some belonging to the water-pipe form provides some indications as to the date of the Iron Age Settlement, since these are generally believed to have been introduced to the native tribes of eastern and southern Africa by Arab hemp smokers.

* It should be mentioned that the ring technique is used by the women potters of the Kikuyu tribe to-day although these pots when broken do not always exhibit horizontal concave-convex fractures. The rings used are considerably larger than those found in the Neolithic vessels, measuring approximately 4 inches in depth and 2 in thickness. Such a ring goes to form the upper half of a vessel and a second of similar dimensions the lower half. When additional clay is needed it is added to the base, which is manufactured last since the pots are worked from the rim (W.S. Routledge, "With a Prehistoric People").

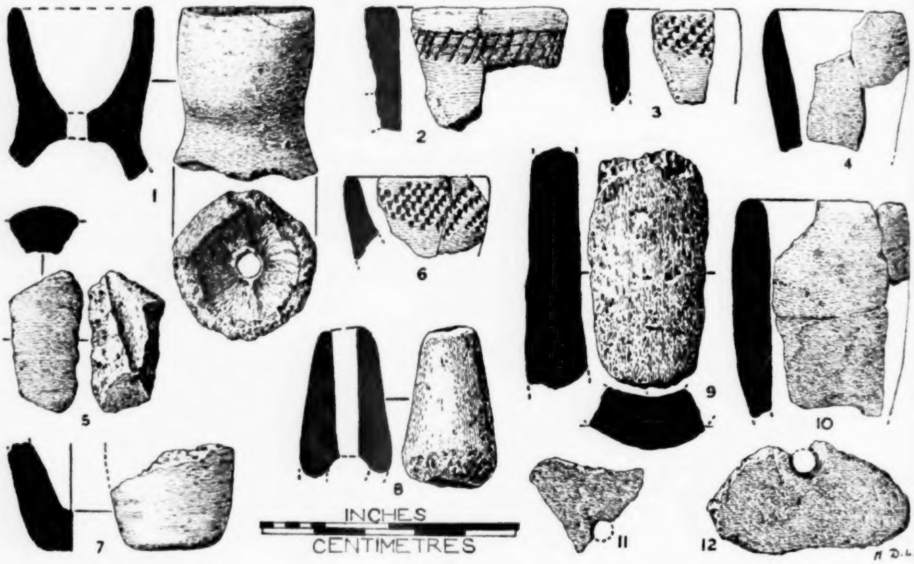


FIG. 17.—The Pottery Pipe Bowls, etc.

(1) Water-pipe bowl of reddish ware. Diameter at the mouth 28 mm., the base is broken away. On one part of the lower edge the surface is not broken and this presumably formed part of the hole for the insertion of the stem. From Cutting Ig, L/1.

(2) Fragment of pipe bowl with a decoration of oblique and horizontal incisions in a horizontal band beneath the rim. Calculated diameter at the mouth 30 mm. This specimen, similar to No. 1, has a small area on the lower edge which is not broken and which may have formed part of the hole for the insertion of the stem. Grey ware. From Cutting IIe, L/1.

(3) Small fragment of pottery pipe bowl with impressed cord decoration at the rim, of which the calculated diameter is 26 mm. From Cutting I, L/1.

(4) Two fragments of an undecorated pipe bowl, heavily blackened on the interior. Calculated diameter at the mouth 28 mm. From Cutting I, L/1.

(5) Fragment of pipe bowl, the rim is not preserved. From Cutting Ih, L/1.

(6) Two fragments of an apparently very shallow bowl with impressed cord decoration. Much blackened on the interior. Calculated diameter at the mouth 28 mm. From Cutting Il, L/1.

(7) Base of a pipe bowl?. From Cutting Ie, L/1,

(8) Fragment of a cylindrical pipe (?) of red ware. From Cutting Ib, L/1.

(9) Fragment of a pottery cylinder, possibly a bellows nozzle?. Very coarse red ware. From Cutting In, L/1.

(10) Three fragments of an unusually large pottery pipe bowl. The interior is heavily blackened. Calculated diameter at the rim 35 mm. From Cutting Ia, L/1.

(11) and (12) Two sherds with repair holes. From layer 1 of Cuttings In and Im.

Although the earliest Arab settlements on the East Coast are recorded by the anonymous author of "The Periplus of the Erithryan Sea" during the first century A.D., it seems reasonable to assume that a considerable period of time must have elapsed before trading became sufficiently well established to penetrate into the up-country district of Nakuru.

4. The Pendants and Shell Ornaments.

Nine pendants were found which, with the exception of No. 3, fig. 18, made of pig ivory, are all made from polished bone splinters. Six of these are sufficiently complete for the shape to be determined. It appears to have been triangular or sub-triangular with a straight base tapering to a pointed or blunt extremity. The pendants vary in length from 1·85 to 0·65 inches and the only decoration is a single incised line parallel to the base. This is present on three examples. Six of the perforations have been drilled from both directions and the remaining three from one direction only.

Four halves of cowrie shells were found which have been identified by Mr. Tomlin of the Department of Zoology, British Museum, as *Cypraea annulus* Linn., a species found on the East Coast of Africa and also in the Red Sea. Owing to the fact that each cowrie has had the convex surface of the shell removed, it seems likely that they were used as ornaments on clothing. It should be mentioned that cowrie shells similarly treated in order to facilitate attachment were widely used as ornaments by East African native tribes until recent years.

A roughly circular perforated fragment of the large land snail *Achatina sp.* was also found.

(*Note.*—The description of the seven beads from the Iron Age settlement will be found with the descriptions of the other beads recovered from the excavations on p. 368. They are illustrated in Pl. XXII, No. 2.)

5. The Iron Objects.

The iron objects recovered were for the most part considerably damaged by oxidisation and in poor condition. They include rings, bracelets, a triangular razor blade, a fragment of a haft possibly belonging to a knife or dagger blade, a multiple barbed arrow or javelin head, an axe, and some small indeterminate fragments.

No trace of decoration can be seen on the rings or bracelets and these call for no comment. The multiple barbed javelin head appears to have had a spatulate tip, two barbs are preserved on it and the broken surfaces on either side indicate that the barbs were originally in opposite pairs.

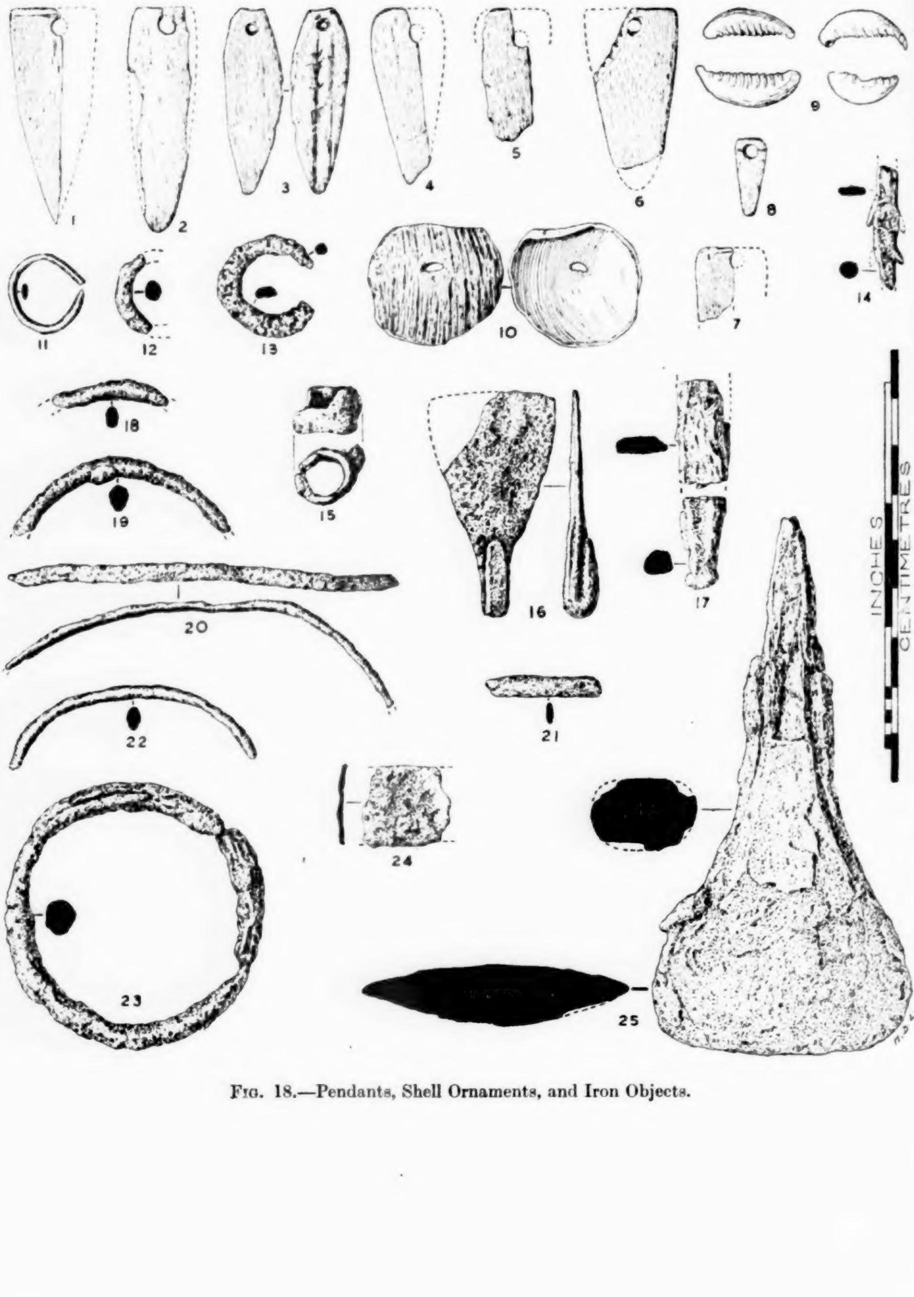


FIG. 18.—Pendants, Shell Ornaments, and Iron Objects.

Although the specimen is incomplete, the rapid thickening of the shaft at the base of the fragment suggests that the original length may not have greatly exceeded the preserved portion.

Triangular razor blades with "folded" butts similar to the specimen shown in fig. 18, No. 16, were widely used by a number of East African native tribes until recent times. The butt end of the small axe or adze is unfortunately so scaled that it is impossible to determine the original form, although it appears to have been slightly waisted and one face is more convex than the other.

6. The Burial Pits.

The nine burial pits discovered south-east of the entrance of Enclosure B yielded the remains of 19 individuals as far as could be ascertained during excavation. With the exception of a comparatively small proportion, the bones were in a very poor state of preservation on account of their proximity to the surface and the method of burial employed. Owing to the fact that

(1) Half a triangular bone pendant with an incised line parallel to the base. Length: 1·8 inches. From Cutting Ia (B. 71).

(2) Blunt-ended bone pendant damaged by rodent gnawing. Length: 1·85 inches. From Cutting IIb (B. 165).

(3) Undecorated pig-ivory pendant. (Complete.) Length: 1·55 inches. From Cutting Il (B. 160).

(4) Half an undecorated bone pendant with asymmetrical point and rounded base. Length: 1·4 inches. From Cutting Il (B. 161).

(5) Fragment of bone pendant. From Cutting Il (B. 163).

(6) Triangular bone pendant, damaged by rodent gnawing. From Cutting Il (B. 162).

(7) Fragment of bone pendant with traces of an incised line parallel to the base, similar to No. 1. From Cutting IV (B. 167).

(8) Small, complete bone pendant with an incised line parallel to the base on either side of the perforation. Length: 0·65 inch. From Cutting IVs (166).

(9) Four fragments of cowrie shells. From Cuttings Ia, If, Il (B. 157–9, 164).

(10) Circular shell ornament. Diameter: 1·1–1 inch. From Cutting IVs (B. 169).

(11) Bronze (?) ring. Internal diameter: *c.* 0·5 inch. From Cutting Ix (F. 7).

(12) Fragment of iron ring. From Cutting Ih (F. 3).

(13) Incomplete, flat iron ring. Internal diameter 0·5 inch. With Skeleton No. 20 in Burial Pit A3. Cutting IV (F. 5).

(14) Fragment of multiple barbed iron arrow or javelin head. From Cutting Il (F. 8).

(15) Broad iron ring. Internal diameter: *c.* 0·3 inch. With Skeleton No. 20 in Burial Pit A3. Cutting IV (F. 11).

(16) Triangular iron razor. Length: 1·85 inches. From Cutting Il (F. 2).

(17) Two haft fragments of an iron implement. From Cutting Ih (F. 16).

(18, 19, 20, 21, 22) Fragments of iron bracelets. From Cuttings IV (F. 12), If (F. 9), Il (F. 4), IV, Ext. N (F. 15) respectively.

(23) Complete iron bracelet. Internal diameter: 1·7–1·8 inches. With Skeleton No. 20 in Burial Pit A3 (F. 6).

(24) Fragment of thin iron band, 0·8 inch in width. From Cutting IV (F. 13).

(25) Iron axe head. Length: 4·4 inches. From Cutting Ih (F. 1).

the greater part of the limb bones were represented merely by shaft fragments, lacking both extremities and crushed beyond recognition, the skulls and teeth alone were used as criteria for determining the number of individuals present in each pit.

The distribution of the remains in the pits was as follows:—

Pit.	Individuals.	Pit.	Individuals.
A1	1	A6	1
A2	5	A7	2
A3	2	A8	2
A4	1	A9	2
A5	3		

The pits were irregularly shaped, with the circumferences roughly circular or oval but generally ill-defined owing to the fact that they had in most cases been sunk into the stony structure of the Neolithic cemetery and subsequently filled with stones. With the exception of Pit A5, some 3 feet deep, in which the lowest interment lay on the surface of the beach material, no pit had been dug below the boulder layer of the Neolithic cemetery, although the upper part of the structure had been considerably disturbed. In all the burials the human remains appeared to have been hastily and carelessly interred, disarticulated limb bones being frequently found perpendicular in the soil with the bones of several individuals intermingled and the whole collection crushed by the stones filling the pits. These appeared to have been thrown in haphazard, regardless of the human remains.

Three articulated skeletons were discovered (Nos. 12, 14, 18), while the bones of the remaining sixteen were found lying in heaps with the skulls detached from the bodies in a number of cases.

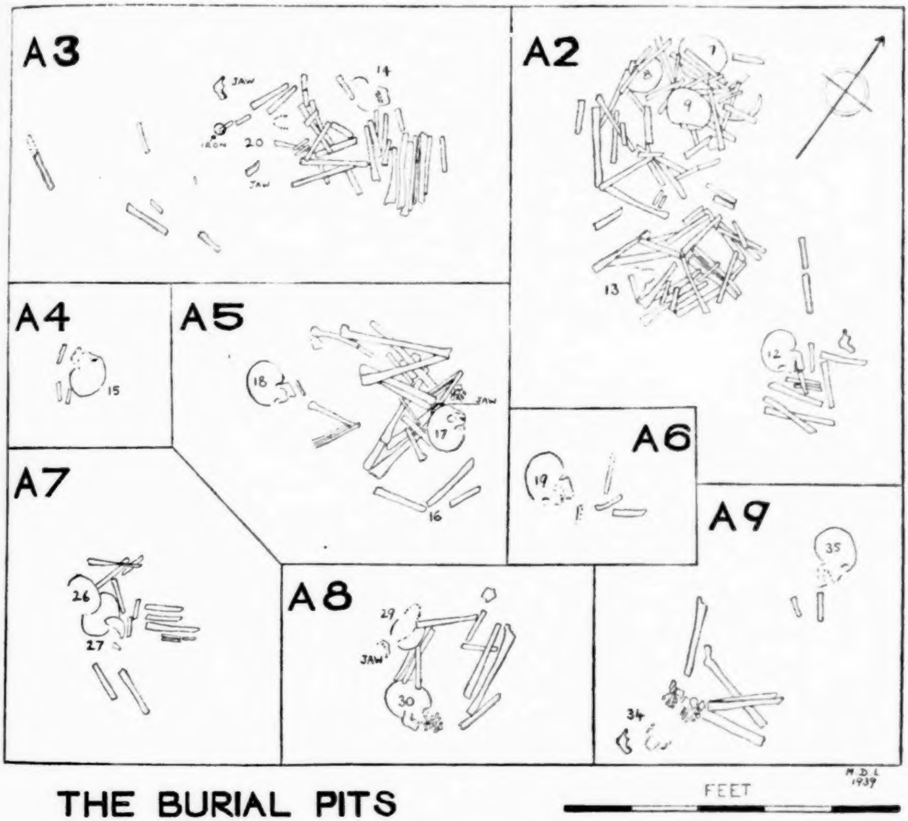
*Pit A*1, *Cutting III.* (Not illustrated.)

Depth *circa* 1·5 feet. Diameter at the upper edge *circa* 3 feet. Contained two fragmentary limb bones and traces of a third.

*Pit A*2, *Cutting III.* (*Pl. XVII, No.* 2 *and Fig.* 19.)

Depth *circa* $2\frac{1}{2}$ feet. N.W. to S.E. diameter *circa* 4 feet. The south-west edge of the pit extended into Pit A3, although the human remains lay in two distinct groups and are therefore described separately. Five skulls were found in A2, namely, Nos. 7, 8, 9, 13, and 14. The number of intermingled limb bones suggests, however, that one, or possibly two, additional skeletons were present. No. 7, a relatively well-preserved skull, lay on its base facing north-east and at a slightly lower level than No. 8, which was on the left

side facing south-west and was very much crushed. No. 9, better preserved than the majority of the skulls although greatly warped, lay on its base in a similar position to No. 7, facing east. The atlas and axis and first cervical



THE BURIAL PITS

THE POSITIONS OF THE HUMAN REMAINS

FIG. 19.

vertebrae were found adhering to the base of the skull, although the remainder of the vertebrae were not present, suggesting that the head may have been severed from the body.

These three skulls lay amongst the group of limb bones in the north-west area of the pit. Owing to the fragmentary condition of the remains, it was

impossible to determine during excavation to which cranium the limb bones belonged. It was clear, however, that no articulated skeleton was present, and it seems likely from the positions of the bones that all the bodies may have been dismembered and possibly decapitated prior to inhumation.

Skeleton No. 13 lay isolated from the others in the pit and appeared to have been buried in an articulated condition. The skull lay on its right side and faced south. The limb bones, although very incomplete, lay in the positions normal for a contracted burial. Two additional limb bones and a mandible were found north of No. 13, apparently disassociated from the other remains in the pit.

Pit A3, Cuttings III and IV. (*Pl. XVIII, No.* 1 *and Fig.* 19.)

Depth *circa* 3 feet. N.W. to S.E. diameter *circa* 13 feet. As has been mentioned, one edge of the pit extended into Pit A2. The joint N.E.-S.W. diameter of the two pits measured approximately 11 feet, A3 being the larger of the two.

Skeleton No. 14 lay in the contracted position on its right side in the north-east area of the pit. Although the skull was very badly preserved, the limb bones proved to be in better condition than usual. They lay almost exactly parallel to one another and close together.

The bones of Skeleton No. 20 were in a very fragmentary condition. This interment was of some importance since it proved to be the only case in which cultural objects other than occasional potsherds were found associated with the human remains. The skull was represented merely by the teeth and palate and had apparently lain in an inverted position. A mandible, presumably belonging to the same individual, was found at some distance from the cranium. An iron bracelet (No. 23, fig. 18) was found encircling two long bones which appeared to be a radius and ulna. Two iron rings were also found near the remains.

In addition to Skeletons 14 and 20, five fragments of limb bones and half a mandible were found in the south-west area of the pit. These probably represent remains of a third individual.

Pit A4, Cutting III. (*Fig.* 19.)

This proved to be a small shallow excavation and contained the skull and three fragmentary limb bones of an immature individual (No. 15). The skull was considerably crushed and had been placed on the right side facing north. It lay against a large stone and had become flattened against it by the weight of the overlying stones.

Pit A5, Cutting III, Ext. N. (*Pl. XVIII, Nos.* 2 *and* 3, *Fig.* 19.)

Depth *circa* 3 feet. N.W. to S.E. diameter *circa* 8 feet. N.E. to S.W. diameter *circa* 9 feet. This pit proved to be one of the most clearly defined owing to the fact that it was situated for the greater part beyond the limits of the Neolithic cemetery structure. It contained three superimposed skeletons of which the uppermost, No. 17, was represented merely by four long bone shafts.

The trunk of No. 16, which underlay No. 17, appeared to have been articulated when buried, although the skull had undoubtedly been removed from the body since it lay in an inverted position, facing north, with the upper cervical vertebrae adhering to the base. The mandible had similarly been detached and lay beneath the frontal region of the skull. The arms were flexed, with the humeri lying on either side of the cranium. These and the remaining bones of the body lay in normal positions and it appeared to have been placed on its back with the legs flexed. No. 18, which lay beneath the two skeletons described above, but in an opposite direction, with the skull to the south-east, had been placed on its back in a flexed position with the skull facing south. With the exception of the ribs, pelvic bones, and scapulae, Nos. 16 and 18 were better preserved than the average.

Pit A6, Cutting IV. (*Fig.* 19.)

Depth *circa* 2 feet. Circular in plan with a diameter of approximately 3 feet. Contained the very fragmentary remains of one individual, No. 19. The skull lay on the right side, facing south. Four fragments of limb bones were also found, all crushed beyond recognition.

(*Note.*—No definite pit could be located where the remains of Skeleton No. 24 were found.)

Pit A7, Cutting V. (*Fig.* 19.)

Depth *circa* 1·5 feet. Diameter *circa* 2·5 feet. The remains of two individuals, Nos. 26 and 27, were found in this pit. Both skulls were present although badly preserved, that of No. 27 lay face downwards, while that of No. 26 was found in three fragments, superimposed on No. 27. All the bones and the crania were considerably crushed and damaged.

Pit A8, Cutting IIIc. (*Pl. XVIII, No.* 4 *and Fig.* 19.)

Depth *circa* 3 feet. N.E. to S.W. diameter *circa* 3 feet. N.W. to S.E. diameter not proved. This pit contained two individuals, Nos. 29 and 30. The skull of No. 29 lay in an inverted position with the mandible 6 inches distant from the palate. Skull No. 30, somewhat better preserved than

No. 29, lay on its left side facing south-east. Neither of these two skulls appeared to lie in natural positions relative to the group of limb bones, and it must be assumed that the remains were interred in a dismembered condition.

A fragment of undecorated pottery, similar in texture and appearance to the ware of the vessel shown in fig. 16, No. 13, was found in the soil underlying skull No. 30.

Pit A9, Cutting IX. (*Pl. XVIII, Nos.* 5 *and* 6, *Fig.* 19.)

Depth *circa* 2·5 feet. N.E. to S.W. diameter *circa* 8 feet. N.W. to S.E. diameter not proved. Of the two individuals contained in this pit, No. 34 was represented merely by half the mandible, the palate and the condyles of the skull. Skeleton No. 35 lay north of No. 34, the skull being on its left side and facing south-east. South of it were found shaft fragments of both humeri. No trace of the vertebrae could be discovered, and the femora, tibiae, and fibulae, together with the foot bones, which were all well preserved, lay considerably farther distant from the skull than would be possible in the case of an articulated skeleton. One femur, moreover, was found some 9 inches higher than the other bones.

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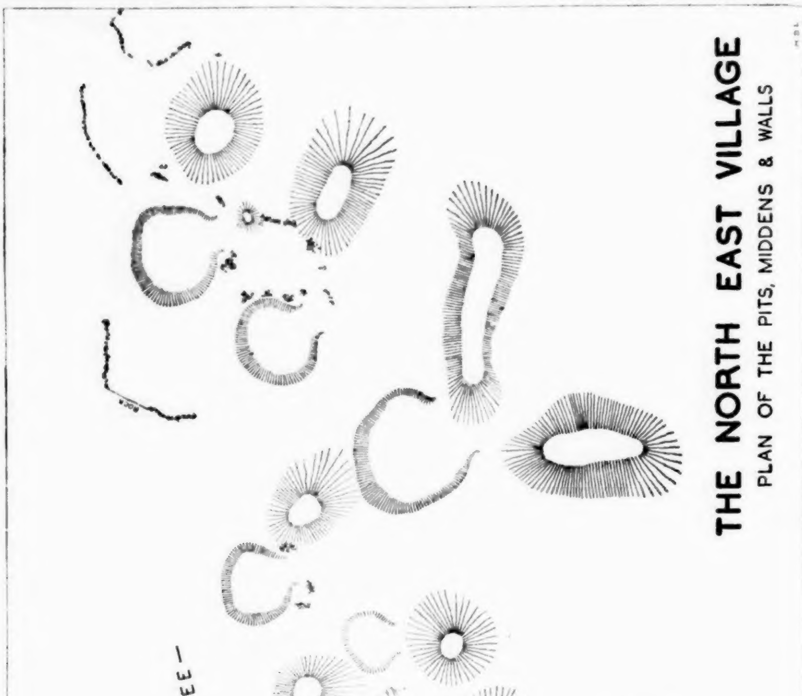


PLAN III.

[To face p. 355.

Mary D. Leakey. *Neill & Co., Ltd.*

PART III.

Site II. The North-East Village.

The group of thirteen pit dwellings which has been named the Hyrax Hill North-East Village, or Site II, was clearly visible before excavations were begun as a series of shallow circular depressions varying from 40 to 90 feet in diameter and accompanied by low mounds (see Plan III). These shallow depressions had been dug into the gentle lower slope of the hill some little distance from the lower limit of the rocks and scree forming the hill proper. The entrances of all the pits faced away from the hill, overlooking the grassy plains in the direction of Menengai Crater.

In the majority of cases a low mound could be seen to the right of the entrance of the pits. These mounds often covered a large area, but were never very high, the maximum height being approximately 4 feet. Subsequent examination revealed that these mounds were middens of ash and soil containing a quantity of broken animal bones, potsherds, and other living-site debris. Wherever rodents or other burrowing animals had dug into the mounds, animal bones, potsherds, etc. were brought to the surface.

1. The Excavations.

Midden A.

The first excavation carried out in the village was a Trial Trench 120 feet long (east to west) by 5 feet wide, which was taken through the large midden (A) from which the two-handled jar illustrated in Pl. XX, Nos. 4 and 5, had been recovered, after it had been exposed in an ant bear hole.

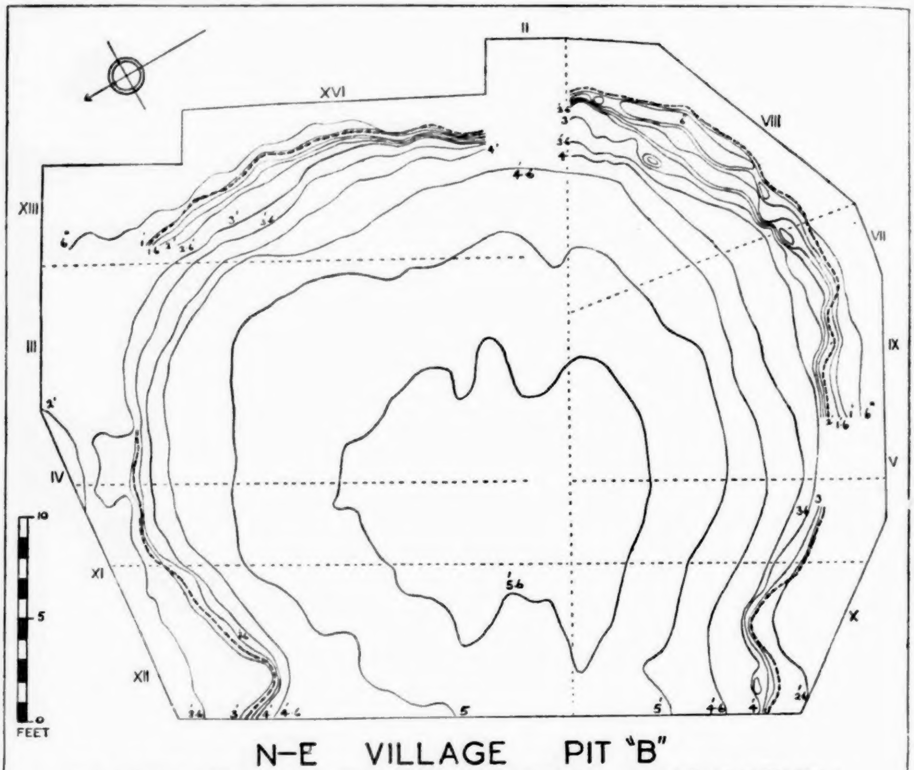
The midden was found to be composed largely of wood ash and contained quantities of animal bones, usually split in order that the marrow might be extracted. Some of these remains have since been identified as belonging to domestic sheep and oxen. The maximum height of the midden was found on eastern side, that is the area nearest to the adjacent large pit dwelling from which the material was presumably derived.

In addition to the handled jar mentioned above, 204 potsherds were recovered, which appear to belong to three or possibly four vessels. Obsidian implements were scarce and only 21 implements were recovered, together with 29 waste flakes and 63 distal fragments of flakes.

Pit B. (Pl. XIX, No. 1.)

A series of cuttings was next made in a medium-sized pit south-west of Midden A. This was eventually cleared to the original floor level. The pit

was found to be flat bottomed, with a maximum depth of 5½ feet in the central portion and roughly circular in shape, with a diameter at the rim of approximately 35 feet (figs. 20 and 21).



N–E VILLAGE PIT "B"
CONTOUR OF THE PIT AFTER EXCAVATION

Fig. 20.

Three Cuttings (II, III, and V) were taken through the pit wall in order to ascertain beyond doubt that the true side had been reached. The walls, although considerably eroded, appeared to have been originally nearly vertical and were best preserved in the rear portion of the pit. Although post holes must necessarily have existed for roof supports, none could be

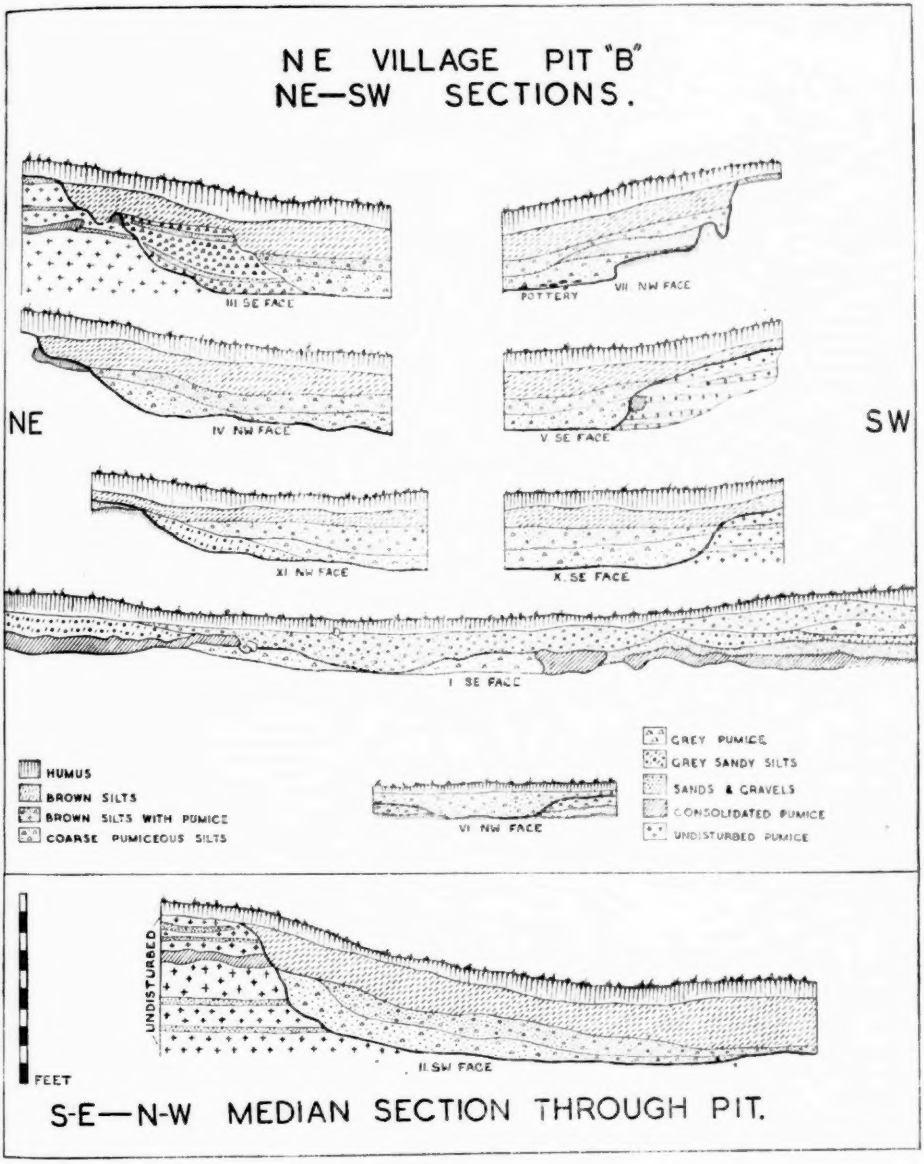

NE VILLAGE PIT "B"
NE—SW SECTIONS.
NE
SW
III SE FACE
POTTERY
VII NW FACE
IV NW FACE
V SE FACE
XI NW FACE
X SE FACE
I SE FACE
HUMUS
BROWN SILTS
BROWN SILTS WITH PUMICE
COARSE PUMICEOUS SILTS
VI NW FACE
GREY PUMICE
GREY SANDY SILTS
SANDS & GRAVELS
CONSOLIDATED PUMICE
UNDISTURBED PUMICE
UNDISTURBED
FEET
II SW FACE
S-E—N-W MEDIAN SECTION THROUGH PIT.

FIG. 21.

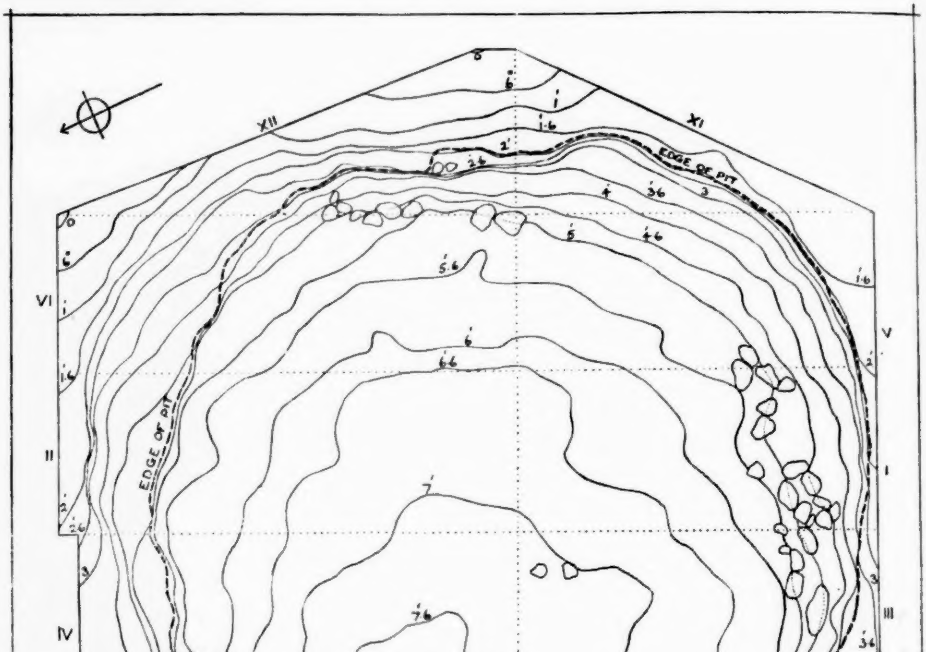

N-E VILLAGE. PIT "C"
PLAN & CONTOUR OF THE PIT
AFTER THE EXCAVATION
EDGE OF PIT
ENTRANCE
HEARTH
GRINDSTONE
FEET

Fig. 22.

p[illegible]ly identified on account of the presence of numerous rodent holes and the unconsolidated nature of the sub-soil which throughout the excavated area proved to be a loose grey pumiceous gravel.

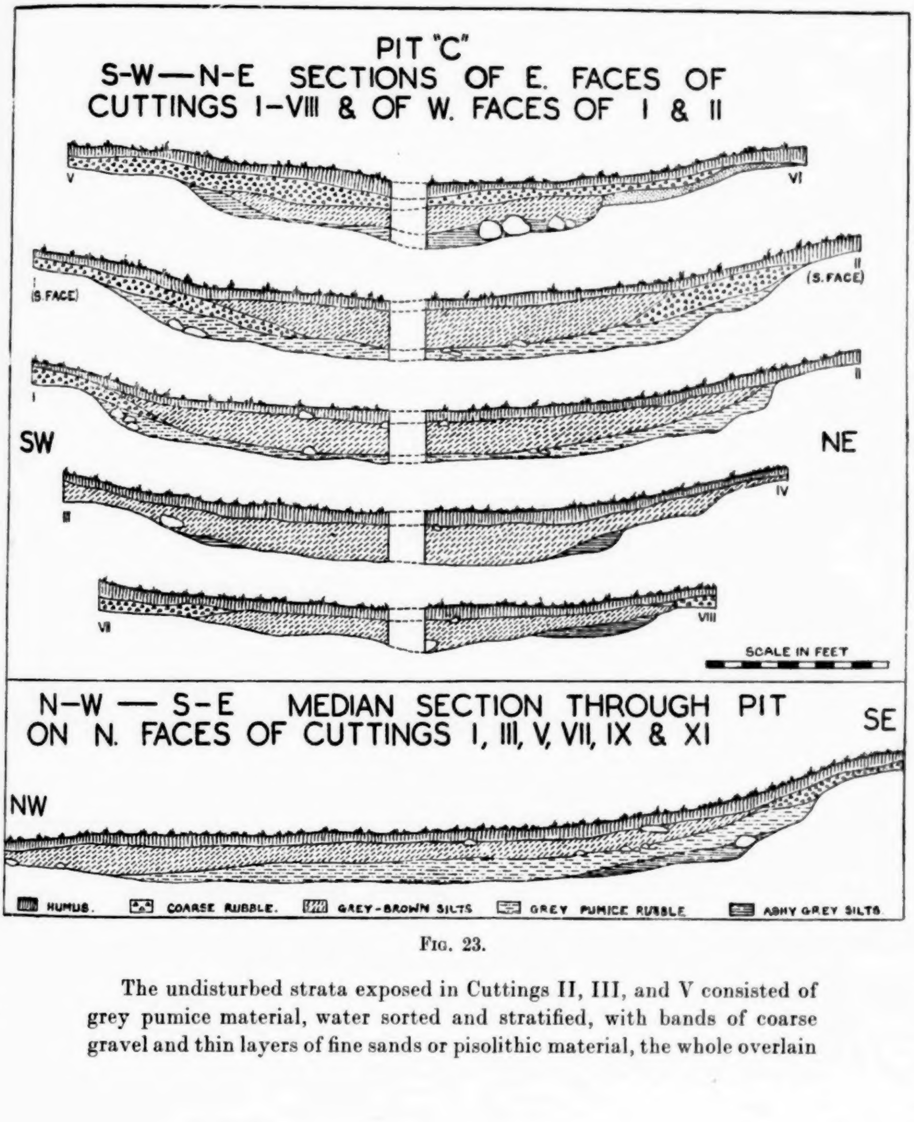


FIG. 23.

The undisturbed strata exposed in Cuttings II, III, and V consisted of grey pumice material, water sorted and stratified, with bands of coarse gravel and thin layers of fine sands or pisolithic material, the whole overlain

by a more consolidated yellowish-white pumice. Blocks of this stratum, fallen from the rim of the pit, were also found in the filling.

The pit was found to be silted to a depth of approximately 4 feet, of which the upper 9 inches consisted of blackish-brown humus. Beneath the humus occurred a stratum 1–3 feet thick, of grey-brown pumiceous silts overlying coarser pumiceous silts usually grey in colour, the lower part of which, immediately above the floor, yielded an abundance of broken animal bones, pottery, and other remains. These were found concentrated in particular in the left-hand rear section of the pit. The area near the entrance was comparatively unproductive and no hearth could be found.

Some 600 potsherds were recovered, representing nine or possibly ten vessels, three of which have been reconstructed (Nos. 1, 2, and 3, fig. 24). 54 obsidian implements, 68 waste flakes, and 93 distal fragments of flakes were also found, together with the only two beads discovered at the site.

Pit C. (*Pl. XIX, Nos.* 2 *and* 3.)

A second pit, lying at a slightly higher level, immediately south-east of Pit B, was next excavated. This proved very similar in size and form to the first, although somewhat deeper, with a maximum depth of 7½ feet in the centre. The transverse diameter again measured approximately 35 feet, although the fact that the entrance was more elongate and considerably better defined gave the pit a somewhat oval form.

The walls sloped more gradually than in Pit B and appeared to have become eroded to a greater extent before the silting took place. The filling, which was similar in strata and composition to that of Pit B, measured approximately 3½ feet in maximum depth. It contained markedly fewer remains, both of animal bones and potsherds. The latter amounted to some 500 small sherds, amongst which four vessels may perhaps be distinguished, although none are sufficiently complete to be reconstructed. 51 obsidian implements, 54 waste flakes, and 111 distal fragments of flakes were also recovered from the filling.

A small hearth, consisting of an area of burned red earth, but without hearthstones, was discovered in the pit, immediately south of the entrance. North-west of the hearth and outside the entrance, a lower grindstone was found lying on the floor level with the grinding surface downwards.

As in Pit B, no post holes could be identified. A number of stones were, however, found in the basal silts near the entrance and around the pit, lying at the foot of the wall, which may be presumed to have been connected with the roofing structure.

2. The Pottery.

The characteristic features of the North-East Village pottery are the presence of spouts and vertically applied handles, together with impressed cord decoration. On two of the four more complete vessels recovered, all of which are globular in form with round bases and straight or slightly everted rims, the spout is combined with a small handle on the opposite side of the pots. These vessels are, in fact, a primitive form of jug. On the third vessel, shown in No. 1, fig. 24, a spout is present but no handle; on the fourth, an unusually large jar, there are two handles but no spout (No. 4, fig. 24).

Approximately sixteen vessels can be distinguished among the 1300 odd sherds recovered from the two pits and from Midden A. Whenever a sufficient number of fragments are preserved for the form of the incomplete vessels to be recognisable, they appear to be analogous to the reconstructed pots, since the bases are invariably round and the rims closely similar. Six fragmentary handles and the remains of two spouts are among the sherds, which also include a considerable number with impressed cord decoration. This usually occurs in a horizontal band beneath the rim and sometimes in additional horizontal and vertical bands on the body of the pot.

The small vertical incisions seen on the reconstructed vessel, No. 2, fig. 24, and a series of semicircular impressions apparently formed by a roller, which are present on a few fragments belonging to a coarse buff pot, constitute the only two variations from impressed cord decoration.

A number of sherds bearing repair holes were also found. These have invariably been drilled after firing.

The wares are all hard and well fired, with fine grits, although the surfaces are rough, gritty to the touch and imperfectly smoothed. Similarly, the impressed cord decoration appears to have been hastily and carelessly applied, no attempt having been made to achieve bands of even width.

Black, buff, red and grey wares are all represented in the series. Although some sherds are uniform in colour throughout their thickness, the most common section is buff-grey-buff with a very superficial blackening of the surfaces. It would seem that such vessels were originally buff or reddish-brown in colour and have become blackened through secondary firing during use. There is no suggestion that burnish was ever employed.

Although the pottery recovered from the Nakuru Burial Site is too fragmentary for the form of the vessels to be determined, these sherds offer the closest similarity to the North-East Village series. Broken spouts, handles, and fragments bearing impressed cord decoration and repair holes were all found in the soil covering the primary interment. The wares are also very similar in texture and degree of hardness.

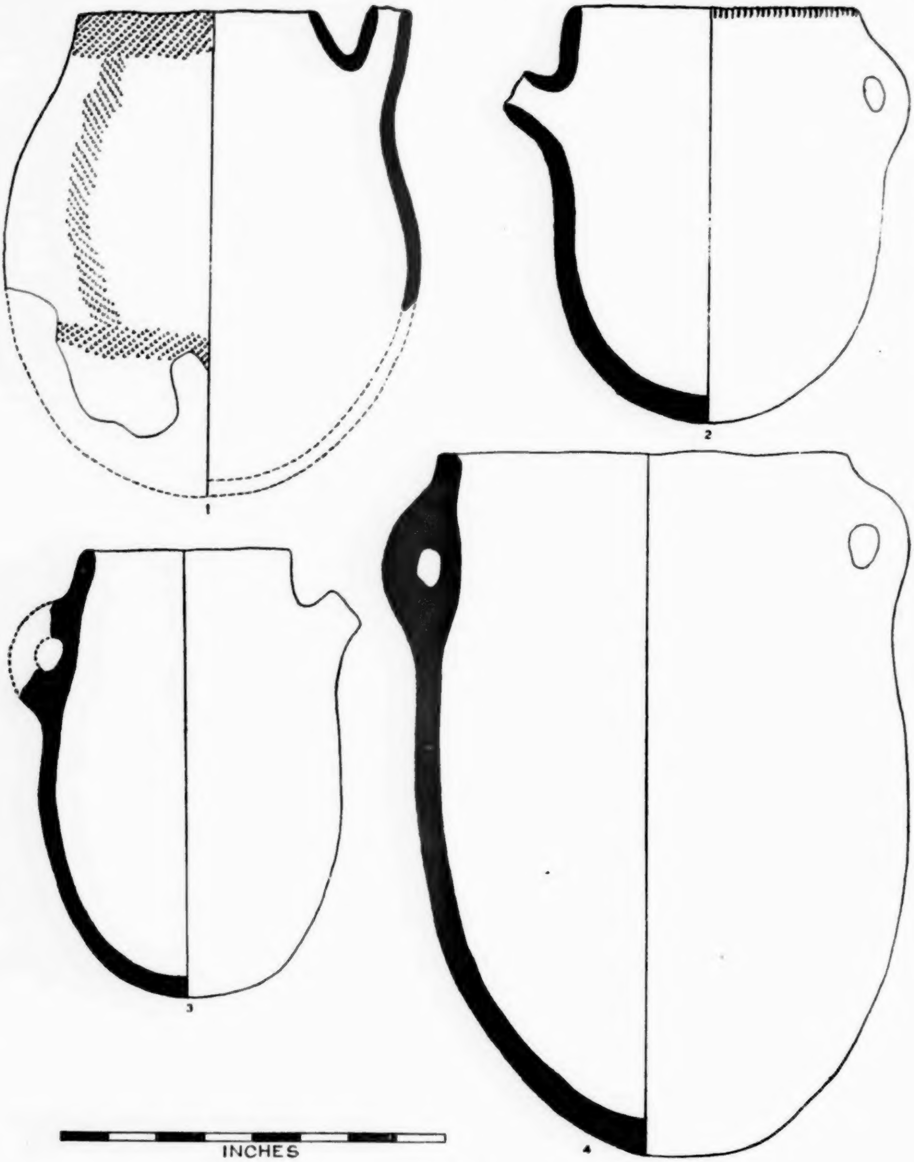


FIG. 24.

Such pottery is not at present known from any other excavated site, although fragmentary spouts and handles, together with cord-decorated sherds, have from time to time been picked up from middens in the vicinity of Nakuru, Molo, and Nanyuki, where large numbers of settlements of pit dwellings and middens, comparable to the North-East Village, are known to occur.

3. The Implements.

Owing to the very small number of obsidian implements recovered from the two excavated pits and from the Trial Trench in Midden A, no measurements have been taken, since the series in addition to being extremely limited also includes a high proportion of broken specimens.

The following tool types are represented in the 126 implements: crescents, 4; burin spalls, 2; end scrapers, 6; trimmed points, 4; backed blades, 3; *lames écaillées*, 4; utilised flakes, 49; cores, 4; fragments of crescents and backed blades, 21; fragments of blade flakes, 16; the waste material amounted to 151 whole and bulbar extremities of flakes and 267 distal fragments. A representative series of the implements is shown in fig. 25. It will be seen that the crescents, backed blades, and end scrapers are crude and ill-made, suggesting a somewhat degenerate industry. Both the tool types represented and the form of the industry are closely comparable to the material recovered from the Nakuru Burial Site.

4. The Faunal Remains.

The animal bones recovered from the two pits and Midden A were submitted in 1938 to Dr. Wilfrid Jackson of Manchester University, who very kindly undertook to make a report on them. The exigencies of war

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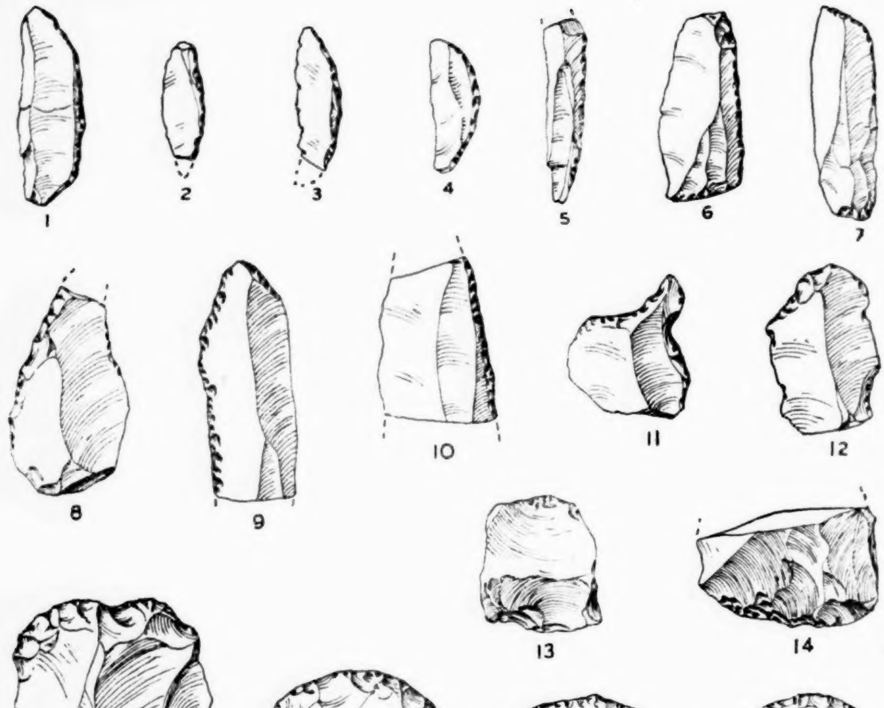
(1) Globular spouted pot from Pit B, Cuttings I, V, VII. Height 10 inches, diameter at mouth 5 inches. Decoration of six vertical bands of cord impressions, linking a horizontal band at the rim to a second horizontal band on the belly of the vessel. (The base and lower part are missing.) Well-fired hard ware, reddish-buff in colour at the mouth, becoming black towards the base on the exterior.

(2) Vessel with spout and handle from Pit B, Cuttings VII and VIII. Height 8·5 inches, diameter at the mouth 5·7 to 6 inches. Decoration of small vertical incisions on the external angle of the rim. Reddish-brown ware, blackened on the exterior surface. The vessel is noticeably asymmetrical and the spout is not exactly opposite to the handle.

(3) Vessel with spout and handle from Pit B, Cutting VII. Height 9·3 inches, diameter at the mouth 4·5 inches. Ware reddish-brown in colour at the mouth and base; black on the belly of the vessel.

(4) Two-handled jar from Midden A, Cutting I. Height 14·5 inches, diameter of the mouth 8·5 inches. Reddish-brown ware, blackened on the belly of the vessel.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M.D.L.
CENTIMETRES
INCHES

FIG. 25.

have, however, rendered this impossible up to date. On receipt of the material Dr. Jackson wrote: "In the top parcels I find a number of bones of sheep and ox . . . most seem to have been split and chopped in order to extract the food value from them, just as one finds in our own kitchen middens of prehistoric date."

Should the material survive until after the war, it is to be hoped that a full report will be published in due course, meanwhile the existence of domestic species of sheep and oxen may be accepted as certain. It should be noted that bones of sheep and oxen were also found at the Nakuru Burial Site.*

5. Notes on the Distribution of Pit Dwellings in Kenya and the Occurrence of Modern Examples in Tanganyika Territory.

To the north and east of Nakuru, within a radius of approximately 80 miles and south, as far as Lake Naivasha, great numbers of pit dwellings are known which, on casual examination, are exactly similar to those of the North-East Village.

The majority are found in groups of twelve or more, usually cut into the slope of a hill but sometimes lying in the open plains. Within two miles of Hyrax Hill, on the eastern slope of Lion Hill and also extending on to the plains below, a particularly large settlement can be seen, comprising over 100 pits with accompanying middens, lying round a roughly circular central area in which only a very few pits occur. This central area is enclosed by a ditch averaging 20 feet in depth which is bridged by a natural rock causeway on the north-west side. The soil excavated from the ditch has been thrown up in a series of mounds and does not form a continuous bank.

* There are indications that the cattle may have been of Zebu stock, since the material sent to Manchester included a number of bifid dorsal vertebrae. These, I am informed by Mr. Hudson, of the Veterinary Research Laboratory, Kenya, only occur in the varieties of humped cattle.

Crescents.—(1) Midden A, C. I. 0·8094. (2) Pit C, C. V. 0·8027. (3) Pit C, C. II. 0·8000. (4) Pit C, C. II. 0·8007.

Backed Blades.—(5) Pit B, C. VII. 0·8126. (6) Midden A, C. III. 0·8083. (7) Pit B, C. V. 0·8119. (8) Midden A, C. III. 0·8084. (9) Pit B, C. III. 0·8106. (10) Pit B, C. VII. 0·8125.

Trimmed Points.—(11) Midden A, C. I. 0·8095. (12) Midden A, C. III. 0·8088.

Lames Écaillées.—(13) Pit B, C. III. 0·8105. (14) Pit B, C. I. 0·8101.

End Scrapers.—(15) Pit C, C. III. 0·8033. (16) Pit C, C. V. 0·8024. (17) Pit C, C. II. 0·8006. (18) Pit C, C. X. 0·8034.

Core.—(19) Midden A, C. III. 0·8093.

Core Utilised as Lame Écaillée.—(20) Pit C, C. XII. 0·8024.

Although no excavations have been carried out at the site, a stone bowl fragment, cord-decorated pottery, and fragments of spouts and handles have been collected from the surface, all of which suggest that the settlement may belong to the Gumban B Variant of the Stone Bowl Culture.

A further group of pit dwellings, popularly described as "Seriqua Holes," is known in the neighbourhood of Eldoret township which is situated on the plateau, 100 miles north-east of Nakuru. This type of pit, of which several hundreds are known, is lined with well-built stone walls and is deeper and smaller in diameter than the type found at the North-East Village and elsewhere in the Nakuru neighbourhood. The Eldoret pits are so far entirely unexplored scientifically, but their state of preservation suggests that they are of comparatively recent date.

In the Kericho and Sotik area there are also numerous groups of pits which are similarly attributed to the "Seriqua." None of these have been excavated, but the material collected from some of the pits which were cut through during road-making included iron slag, clay nozzles for bellows, an iron arrow-head and a quantity of undecorated pottery. No stone implements could be found. It may be assumed that this group of pits is later in date than the North-East Village, although the fact that a number of stone bowls have been found near Sotik suggests the possibility that earlier pits may also exist in the area.

Modern examples of the stoneless type of pit can be seen to-day in the Mbulu Highlands, roughly 250 miles south of Nakuru, in the Northern Province of Tanganyika Territory. These pit dwellings are constructed and used by members of the Iraaq tribe, some of whom state, however, that their people have only recently adopted this type of dwelling as a defensive measure against hostile neighbours.

The pits, some of which measure as much as 80 feet in diameter, are partitioned off into a number of rooms by means of roughly hewn planks; the rear portion of the pits being occupied by the members of the family, whilst the cattle and goats are penned overnight into the outer section. Flat roofs are always used, on top of which some of the earth excavated from the pit is often piled. When not used as threshing floors or for any other purpose, those roofs rapidly become masked by vegetation and effectively conceal the dwellings. In fact, Iraaq villages are almost invisible unless seen from below where a number of dark slits are discernible in the hillside, denoting the entrances to the pits.

Rubbish mounds are frequently to be seen standing outside the Iraaq houses, and it is probable that the North-East Village of Hyrax Hill and other contemporary settlements in the district were very similar in appearance when they were in use.

Very little is known concerning the Iraaq, who appear to be physically

and linguistically distinct from their Bantu neighbours. Moreover, since at present their material culture is said to be mainly derived from nearby tribes, it is impossible to state without considerable research whether or not cultural affinities with the Kenya pit-dwellers have ever existed.

REPORTS ON THE BEADS FROM SITES I, II.

I. The Beads from the Neolithic Cemetery.

One stone bead and three other small beads were found in the graves. These last were at first considered to have been made from segments of bird bone, but subsequent examination indicates that the material is probably of vegetable origin and it is suggested that the beads may have been manufactured from some particularly hard and durable type of seed coat. All four beads appear to be of local manufacture.

The stone bead which was found together with one small seed bead in the grave of Skeleton H.H. 21 is similar in all respects to the oblate disc stone beads from the Njoro River Cave, of which over 500 have recently been found. The measurements are as follows: length, 3 mm.; width, 10·5 mm.; diameter of the perforation, 1·5 mm. This appears to have been carried out from both directions and to be chipped rather than drilled or ground. The bead appears to have been made from a common opal or chalcedony; it is very hard, semi-translucent, and yellowish-white in colour.

Both common and fire opals together with agates, cornelians, etc. are known to occur in the volcanic tuffs of the Mau Escarpment near Njoro, some 20 miles distant from Hyrax Hill. It may therefore be assumed that the material is of local origin.

In this connection it is interesting to note that a large number of mines cut into the rock of the Mau are still to be seen at Njoro and also in the neighbourhood of Molo. Little or no information is available concerning the date of these mines or as to the people responsible, although it is almost certain that they have not been in operation since the arrival of the Europeans. The tool marks shown on the walls of the galleries and of the more superficial workings suggest that the miners employed metal tools.

It seems probable that the semi-precio s stones first discovered by the makers of the Stone Bowl Culture were sequently exploited on a considerable scale, stimulated, perhaps, by erland or coastal trade, when the introduction of metal would offer greater acilities for working the mines.

The three small beads, two of which wer[?] found in the dual interment in Mound E, again provide a parallel with the Njoro River Cave where, owing to the conditions of preservation being unusually good, no less than 4000

specimens were recovered, comparable in every respect to the three from Hyrax Hill.

The beads measure approximately 2·5 mm. in length and 3 mm. in width. The walls are extremely thin and brittle, measuring less than half a millimetre in thickness. As a result, the perforation is comparatively wide. Neither the exterior nor interior surface shows any trace of human workmanship, although both extremities have been cut and polished. The general form of the beads suggests that an unusually hard-coated seed, possibly of a grass allied to *Coix lacryma jobi* which is indigenous and used for the same purpose by some modern East African tribes, may have been employed. If this is the case, both extremities would have been cut off, retaining the central segment of each seed.

The perishable nature of the material, which must be regarded as of vegetable origin in view of the examination carried out by Dr. Ballin, suggests that a far greater number of these beads were probably present in the graves, most of which have decomposed, owing to the exposed position of the site.

Report on the Examination of some Beads from Hyrax Hill, Nakuru, by Dr. Otto Ballin.

These beads were too brittle to be sectioned or ground for microscopic examination. However, in thin layers at the edges of broken pieces there appeared distinct evidence of cellular structure.

In the crucible the beads blackened and burned, leaving a white ash, largely insoluble in acid.

Kjeldahl's test showed 2 per cent. Nitrogen. This would correspond to only 1·25 per cent. Protein, a rather small quantity in organic material.

The structure, the presence of a fair amount of carbon, and the fact that no Ammonium could be detected (to account for the inorganic Nitrogen), are very strong indications that the material is of organic origin.

(Signed) O. Ballin.

Nairobi, *October* 1941.

2. The Beads from the Iron Age Settlement at Site I.

Seven beads were recovered from the settlement, consisting of five glass beads, one pottery ring bead, and one of ostrich eggshell. The series is shown on Pl. XXII and the measurements are as follows:—

(3) X. 5. Deep blue cane glass cylinder. Length 6·5–5·5 mm. Diameter 6–4·5 mm. (Cutting Ij.)

(4) X. 6. Deep blue cane glass cylinder, similar to above. Length 5·5–7 mm. Diameter 4·5–7 mm. (Cutting Ik.)

(5) X. 4. Blue cane glass cylinder with iridescent patina. Length 4·5–5 mm. Diameter 4–5 mm. (Cutting Ih.)

(6) X. 3. Red on green glass disc. Length 4–5 mm. Diameter 5 mm. (Cutting Ih.)

(7) X. 8. White cane glass disc. Length 3·5 mm. Diameter 3·5 mm. (Cutting V.)

(8) X. 2. Pottery ring. Length 6·5–8 mm. Diameter 16·5–17 mm. (Cutting Ih.)

(9) X. 1. Ostrich eggshell bead. Length 1·5 mm. Diameter 5–5·5 mm. (Cutting Ig.)

Report on the Iron Age Beads, by the late H. C. Beck, Esq., F.S.A.

X. 5 and 6. These are glass beads resembling the blue glass beads and bracelets of the La Tène period. The cobalt band is not very strong and the colour seems to be due to a mixture of cobalt and copper similar to the analysis of Cooke.

X. 4. This is a cane glass bead. I cannot recollect having seen a quite similar specimen, so I do not like to suggest any date though I should think it is not more recent than the Roman period.

X. 3. This is a sample of a very common type of bead. Vast numbers have been sent out from Europe as trade beads. One shipload of them was wrecked off the Scilly Isles about 150 years ago and specimens are still frequently found there on the sandy beaches; but this is not the whole case. I have seen strings of them sold as Egyptian and have myself a closely allied specimen, which from the way it was found cannot possibly be more recent than A.D. 200.

X. 8. This is a cane glass bead. It is disc shape. The inner layer round the perforation and the outer layer are of a denser nature than the remainder of the material. The glass has a large number of bubbles. It suggests a very roughly made bead.

X. 2. This is a difficult bead to date. Identical beads are found in large numbers in the Damascus bazaars. They are unfortunately not dated, but I believe that their date would be between A.D. 1 and 500. On the other hand, I have specimens which were reputed to have been associated with beads which dated some centuries earlier.

With the exception of X. 1 and possibly of X. 2, the beads must be regarded as foreign to the district, presumably imported as trade goods. The report supplied by Mr. Beck suggests the possibility of a Mediterranean origin for the imported series. The evidence as to dating is, however, extremely inconclusive since the types of beads represented include specimens which may have been manufactured during the early centuries A.D., and one which although known to occur at that period also persisted until the eighteenth century.

Mr. J. F. C. Schofield, of Durban, who has examined the series, remarks on the resemblance between the blue cane bead X. 4 and one obtained from Parma Kopje, in the Limpopo valley (10). He suggests a possible relationship. He also comments on the fact that the white bead X. 8 appears to be similar to, but smaller than beads from N. Rhodesia which are worn by present-day natives. Regarding a date for the series, Mr. Schofield concludes by saying that: "The beads suggest an early nineteenth century date for the settlement, but that is, of course, judged by our standards."

It should be mentioned that blue cane glass beads similar in form although not in colour to Nos. 1, 2, and 3 have been collected from the beach at Zanzibar. The blue in these beads is not nearly so deep as in the Hyrax Hill specimens and tends rather to be a light blue-green. Unfortunately there is no means at present of dating these beads.

Although the possibility of a date as recent as the eighteenth century cannot be overlooked, it seems likely that the settlement should be placed somewhat earlier in view of the occupation of the district by the Masai tribe and the lack of cultural objects belonging to that tribe within the settlement. Amongst these should be mentioned the blue glass annular and red on white disc beads which are known to have been used by the Masai during the eighteenth century and which are still cherished as heirlooms till the present day.

3. Notes on the Two Beads from the North-East Village.

Both these beads were found in Pit B and were derived from the basal silts near the entrance.

No. 1 (*Pl. XXII, No.* 10).—This is a white bead. Length 4–4·5 mm.; width 6 mm.; diameter of perforation, which is parallel sided, 2 mm. Mr. Schofield has examined the bead and suggests that the material may be shell. This seems probable, since the material is very soft and although the bead approximates the cane glass form, such striations as are present run across instead of down the barrel, which would be normal in a cane glass bead. Similar beads are said to have been found on Pemba Island.

No. 2 (*Pl. XXII, No.* 11).—This is an opaque red cane glass bead. Length 5 mm. (max.), 3 mm. (min.); width 4–4·5 mm.; diameter of perforation, which is parallel sided, 1·2 mm. Very fine black streaks are present on the barrel, running lengthwise.

A number of cane glass beads which are similar in form and colour have recently been found on the beach at Zanzibar. The glass in these beads, however, shows numerous small air holes which do not occur in the Hyrax Hill specimen. In spite of this, the similarity between the beads is so great that it seems probable that there must be some connection.

SUMMARY AND CONCLUSIONS.

I. *The Hyrax Hill Variant of the Stone Bowl Culture.*

The material from this occupation provides analogies with Phases B and C of the Upper Kenya Aurignacian and with the Gumban A Variant of the Stone Bowl Culture. The obsidian industry stands very close to the Aurignacian, although the proportion of tool types is not identical and the Hyrax Hill industry, taken as a whole, is noticeably more microlithic. In addition, some forms, such as *lames écaillées*, are not found in the Aurignacian.

The pottery, of which the characteristic forms are ovoid beakers and wide-mouthed bowls, is very similar to that of the Gumban A, although the internally scored bowls of the Gumban A do not occur at Hyrax Hill. Nevertheless, in form, rim types, wares and decoration, a very close connection can be said to exist.

Similarly, low, stone-covered burial mounds with central graves containing contracted interments are also characteristic of the Gumban A. Unfortunately, insufficient of these burials have been excavated to ascertain whether stone platters are a prerogative of the female interments, as they are at Hyrax Hill.

Two racial elements appear to be represented among the skulls, an ultra-dolichocephalic and a mesocephalic. Both of these types have previously been discovered in association with the Elmenteitan culture at Bromhead's Site.

The dating of the Neolithic occupation and of the cemetery remains uncertain. On the evidence of the raised lake beaches it can, however, be placed subsequent to the maximum of the Makalian Wet Phase which has provisionally been dated as *circa* 6000 B.C. It may also be assumed to antedate the arid period between the Makalian and Nakuran Wet Phases when Hyrax Hill must undoubtedly have become uninhabitable.

In this connection, it is interesting to note that the Gumban A sites in the neighbourhood of Elmenteita appear to be confined to the banks of streams and rivers; in other words, to areas where permanent water could be obtained when the lake level had receded and the water had consequently become too alkaline for human consumption, as it is under present-day climatic conditions.

Since the Gumban A appears to be a direct derivative of the Hyrax Hill Variant of the Stone Bowl Culture, it is tempting to postulate that it may have existed during the period when an increasingly dry climate drove the people to abandon their former sites by the lake shore in favour of permanent fresh water near rivers.

II. *The North-East Village.*

There seems little doubt that this site is connected with the Gumban B Variant of the Stone Bowl Culture.

The occurrence of pottery spouts and handles in conjunction with impressed cord decoration provides a link. Remains of domestic sheep and oxen are also known from both sites. In addition, the soil covering the primary interment at the Nakuru Burial Site (Gumban B) consisted largely of wood ash and living-site debris, and was, in fact, composed of the same materials as the midden excavated in the North-East Village.

There are, however, two notable points of dissimilarity at the two sites. Considerable quantities of fish bones were recovered from the midden material at the Nakuru Burial Site: none were found in the North-East Village. Nor were any stone bowls found, although these were particularly plentiful at the Nakuru Burial Site.

The two beads recovered from Pit B imply a connection with coastal trade, since analogous specimens are known from Zanzibar and Pemba Island. If such a connection did exist, it is possible in view of the paucity of obsidian implements at the site that metal tools may already have been known, although still very scarce. Their rarity might explain why none were found, since they would be highly valued and carefully preserved. This, however, is an extremely tentative suggestion, since there is no evidence in support of it.

Although a connection between the two sites seems clear, it is likely in view of the vast numbers of settlements similar to the North-East Village which are to be found throughout the Nakuru district, that the Gumban B tradition was of considerable duration and that the North-East Village represents a later phase than that of the Nakuru Burial Site. This has provisionally been dated *circa* 850 B.C.

Pit-dwellings of this type and pots with spouts have ceased to be used by Kenya tribes of to-day, although impressed cord decoration still remains the most popular motif. A modern parallel for the type of dwellings is, however, provided by the Iraaq tribe in Tanganyika Territory.

III. *The Iron Age Settlement and Burial Pits.*

Very little can be said regarding the people responsible for this occupation since only one skull is reasonably well preserved, nor is exact dating possible.

It should be mentioned that other stone-walled enclosures and hut circles similar to those at Hyrax Hill occur in the Nakuru district. One group which lies on the east of the small kopje on which the Nakuru Burial Site is situated, is within half a mile of Hyrax Hill. Another larger settlement

was recently discovered on a farm some 5 miles distant. Neither of these sites has been excavated.

The fact that contact with the coast existed, as evidenced by the beads, cowrie shells, iron objects, and water-pipe bowls found in the Hyrax Hill enclosures, suggests a date subsequent to the inauguration of Arab trading in East Africa during the first century A.D. A forward limit may also be reached owing to the occupation of the district by the Masai tribe, who are clearly unconnected with the settlement, and who are reputed to have lived in this area for one or possibly two centuries before the arrival of the Europeans during the nineteenth century.

Since the pot forms, impressed cord decoration, type of razor blade, and the use of cowrie shells for decorative purposes on clothing all persist among modern East African tribes, it is likely that the settlement should be placed within the latter half of the period in question rather than earlier. A more detailed study of the beads than has been possible under war conditions may well provide a more exact dating.

No clue could be discovered during excavation as to the reason for the apparently hasty burials in the pits of individuals who for the most part proved to be young men. The fact that some of the bodies had been decapitated and others dismembered may indicate that they were killed for punitive reasons. Nor is it impossible either that these remains are the result of cannibalism. Although no trace of charring was discovered on the bones, the fragment of infant's skull discovered near the hearth in Hut C might be regarded as lending support to this interpretation.

It is, of course, by no means certain that the remains in the pits are those of the people who occupied the stone enclosures. They might equally well be members of another tribe killed in battle. It seems clear, however, that the pit burials are contemporary with the stone enclosures.

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PART IV.

NOTES ON THE SKULLS AND SKELETAL MATERIAL FROM HYRAX HILL.

By L. S. B. Leakey, M.A., Ph.D., F.S.A.

I. The Neolithic Cemetery.

No. H.H. 1.

This individual is represented by a skull with mandible and a fragmentary skeleton. It is apparently an adult female of about 20 to 25 years of age.

The Skull.—This is not complete, but the missing parts are such that it has proved possible to make a reasonably accurate reconstruction. The principal missing parts are: (1) The greater part of the occipital bone except for the area in the immediate vicinity of the lambda suture and a part of the basi-occipital. (2) Part of the right temporal including the mastoid. (3) A large part of the face, especially round the nose. (4) Part of the palate. (5) The nasal bones. The skull is slightly warped by earth pressure, the area most affected being the right parietal.

The Mandible.—Although considerably broken and crushed, it was possible to make a reasonably accurate reconstruction of the mandible. The mandible is weak and the mental eminence only slightly developed.

The Teeth.—The dentition is complete, the third molars are fully erupted and were just coming into wear at the time of death.

General Notes on the Skull and Mandible.

The skull is a small one with bulging parietal bosses and is of the shape generally described as pentagoid. The frontal bone is somewhat receding and the external orbital angles are very weakly developed. The area of the superciliary and supra-orbital bosses is remarkably smooth and of an infantile type. The left mastoid, which is intact, is very small. The principal sutures, other than the basi-occipital, are open. Although the palatal area is much damaged, enough is preserved to show that the palate was of the deep type. There is a good deal of subnasal prognathism (see fig. 26).

As regards the teeth, the upper central incisors are large and the lateral incisors unusually small. The upper third molars are greatly reduced in size and bear a superficial resemblance to premolars. The corpus of the mandible is not markedly lower in the region of the third molars in comparison to the height of the symphysis.

The whole skull and mandible bears a marked resemblance to the skull

F.1 in the series from Bromhead's Site, Elmenteita, described and figured in "Stone Age Races of Kenya Colony." The Elmenteitan skull F.1 was regarded as an intrusive physical type and differed markedly from what is known as the Elmenteitan race.

Measurements.—The following measurements of the skull and mandible were taken in accordance with the methods described in "Stone Age Races of Kenya Colony," pp. 37 *et seq.*:—

L′	180·5	U	508 ?	G2	34 ?
L	181·5	PH	..	EH	18 ?
B	140	G′H	64·5 ?	GL	94
B1	94	GB	..	fml	..
B2	94	J	..	fmb	30
B3	99	NHL	49 ?	P∠	..
H′	122 ?	NHR	49 ?	N∠	72° ?
H	122 ?	NB	..	A∠	69° ?
OH	105·5	DS	..	B∠	39° ?
LB	95·5	DC	..	100 B/L	77·08 ?
Q	289	DA	..	100 H/L	67·27 ?
Q′	291	O1R	..	100 H/L′	67·68 ?
S	..	O1L	..	100 B/H	114·75 ?
S1	125	O2R	..	100 NB/NH(L)	..
S2	135	O2L	..	100 O2(R)/O1(R)	..
S3	..	G1	..	100 G2/G1	..
S′3	..	G′1	..	100 fml/fmb	..
				100 DS/DC	..
				100 SS/SC	..
				100 EH/G2	..

The Mandible.—Owing to the fragmentary condition of the mandible very few accurate measurements are possible. The following are the only measurements that can be given:—

W2	81 mm.	G′2	38 ? mm.
H1	29 (?) mm.	cycr	33 mm.
crcr	81 mm.	cyl	11·5 mm.
rb	35·5 mm.	cyb	8·5 mm.
rb′	32·5 mm.		

It will be seen that this skull falls into the mesocephalic group with an index of 77·08, a breadth-height index of 114·75 and a length-height index of 67·27; figures which compare closely with the corresponding 80·44, 112·90, and 71·26 of the skull F.1 in the Elmenteitan series. The angles of

the facial triangle also compare closely with those of the Elmenteitan skull F.1.

The Skeleton.—The following parts of the skeleton are preserved: both femora shafts, in a fragmentary condition; both tibiae in a similar condition; both humeri shafts, the left having a part of the distal articular surface preserved; a few small shaft fragments of radii, ulnae, and fibulae; fragments of both clavicles; a fragmentary scapula and parts of one innominate bone.

All the shaft fragments indicate a very small individual. It is unfortunate that neither femur is complete, since it would be interesting to estimate the stature. From the parts preserved one is led to infer that the individual was no taller than a present-day pigmy. The innominate bone fragment is clearly that of a female.

The Femora Shafts.—Besides their small size these are remarkable for an extreme degree of tortion. The pilastric region is very feebly developed. The following are the only measurements which can be taken with any degree of accuracy:—

Pil. A.P.D.	Pil. T.D.	100 A.P.D./T.D.
R. 23	21	109·52
L. 24	22	109·09

It can be stated with reasonable certainty that the femora when complete were not more than 410 mm. long.

No measurements are possible on any other parts of the skeleton.

No. H.H. 2.

This individual is represented by a fragmentary skull and mandible and parts of the skeleton, it is apparently a male of advanced age.

The Skull.—The skull is very incomplete. The whole of the face and the greater part of the right side are missing. Both the external orbital angles and both the basal condyles of the occipital are also missing. The parts which are preserved show certain remarkable features, namely, that although the left superciliary ridge is very strongly developed, more so than in any E. African prehistoric skull I have seen, the conformation of the frontal in the direction of the broken external orbital angles suggests that the supra orbital bosses were very weak and that the external orbital angles were of slender proportions.

Although the skull is massive, the mastoids are very small. The articulation for the mandibular condyle is unusually large.

The only measurements possible on the skull are the length, breadth,

basi-bregmatic height which is greater than the breadth, and the sagittal measurements:—

L	192·5	S	384
B	140·5	S1	135
100 B/L	72·98	S2	131
H	142	S3	118
100 H/L	70·74	S′3	99
100 B/H	98·95	Occipital index	60·79

The Mandible.—The only part of the mandible which is preserved is a fragment of the left ascending ramus, together with portions of the left corpus. This contains no teeth and the area of the 2nd and 3rd molars shows a high degree of alveolar absorption, indicating that the teeth were lost some considerable time before death. Two lower central incisors were the only teeth found with this skull and mandible.

The Skeleton.—The following fragments of the skeleton are preserved: the shafts of both femora; the greater part of the right tibia and a shaft fragment of the left; parts of the shafts of both humeri, both radii, both ulnae, both fibulae; a fragment of innominate bone and one astragulus.

Of these skeletal fragments, the only bones on which measurements of any value can be taken are the femora, on both of which the pilastric and platymeric diameters are preserved. The values of these are as follows:—

	Plat. A.P.D.	Plat. T.D.	100 A.P.D./T.D.	Pil. A.P.D.	Pil. T.D.	100 A.P.D./T.D.
R.	31	36	86·11	32	25·5	125·49
L.	29	38	76·31	29	25	116·00

The fragment of innominate bone and the femora shafts suggest male sex, thus confirming the diagnosis based on the skull.

No. H.H. 3.

This individual is represented by a few fragments of limb bones and the following teeth: 3 upper molars; 2 upper pre-molars; 3 lower molars; 2 lower premolars, and 1 canine. Neither the skull nor the mandible are preserved.

The Skeleton.—The only measurements possible are the pilastric diameters of the femora shaft fragments, these are:

	Pil. A.P.D.	Pil. T.D.	100 A.P.D./T.D.
R.	32	30	106·66
L.	32	29	110·34

There is nothing to indicate the sex of the individual. The teeth, which are slightly worn, suggest that it was mature at the time of death.

No. H.H. 4.

This individual is represented by a very fragmentary skull and mandible, together with some parts of the limb bones.

The Skull.—The only parts of the skull preserved are: part of the frontal, part of the right parietal, part of the occipital, and a few small fragments of the temporals and the left parietal. No measurements are possible.

The Mandible.—The greater part of the left side of the mandible is preserved but without either the condyle or the coronoid process. It contains no teeth; and the advanced alveolar absorption indicates that all the teeth were lost a considerable time before death.

Teeth.—One very worn upper premolar is preserved.

The Skeleton.—The following parts of the skeleton are preserved: both femora shafts in a fragmentary condition; a piece of tibia shaft; shaft fragments of both humeri and of both radii. The only measurements that can be taken are the pilastric and platymeric diameters of the femora, which are as follows:—

	Plat. A.P.D.	Plat. T.D.	100 A.P.D.T./D.	Pil. A.P.D.	Pil. T.D.	100 A.P.D./T.D.
R. .	24	36	66·66	31	25	124
L. .	23	37	62·16	31	25	124

There is nothing to indicate the sex of this individual except that the femora fragments are more massive than those of known females in the series and may, perhaps, be regarded as suggesting a male. The one very worn premolar and the great alveolar absorption in the mandible seem to indicate an elderly individual.

No. H.H. 5.

This individual is represented by a skull and mandible and fragmentary skeleton of about 20 years of age. It is probably male.

The Skull.—The skull is so badly warped by earth pressure that no measurements can be taken. The following points are, however, worthy of mention: the frontal bone has a very weak development of the superciliary and supra-orbital bosses, and the external orbital angles are very slender. The palate is very deep, *circa* 18 mm.

The Mandible.—The mandible is well preserved and the only parts missing are the left condyle and coronoid process. All the teeth were present at the time of death, but the incisors, the right canine, and both right premolars have all broken off at the alveolar margin leaving the roots

in the sockets. The mandible is strongly built and probably that of a male. The following measurements have been taken:—

W2 . . .	95 mm.	G'2 . . .	43 mm.
H1 . . .	28 mm.	cycr . . .	37·5 mm.
zz . . .	47 mm.	cyl . . .	20·5 ? mm.
rb . . .	42·5 mm.	cyb . . .	10 mm.
rb' . . .	41 mm.	m2pl . . .	30 mm.

The Teeth.—In the maxillae the following teeth are preserved: all the molars; both left premolars and canine; the 2nd premolar on the right side. The teeth are very little worn, but the 3rd molars are fully erupted and just coming into wear, these are greatly reduced in size and superficially resemble premolars.

The Skeleton.—This is represented by a number of fragmentary limb bones, two damaged astraguli, two damaged calcanii and the atlas. The only measurements that can be taken are on the femora and humeri shafts; the former are remarkable for the extreme degree of curvature seen on the right shaft, while the left is normal. Although the articular ends of the femora are missing, it is possible to say that a short, thick-set individual is represented since the shafts are unusually short in view of their massiveness. The following are the femora shaft measurements:—

	Plat. A.P.D.	Plat. T.D.	100 A.P.D./T.D.	Pil. A.P.D.	Pil. T.D.	100 A.P.D./T.D.
R.	..	..	77·41	29	25	116
L.	.24	31		30	25·5	117·64

The Humeri.—On the shafts of the humeri the following measurement can be given:—

	Mid Shaft Max.	Mid Shaft Min.	Min. Circ.
R. . .	21	17·5	60
L. . .	21	17·5	60

No measurements are possible on any of the other skeletal fragments, which include fragmentary clavicles, tibiae and radii shafts.

The individual is in all probability a young male who had just reached maturity at the time of death.

No. H.H. 6.

This individual is represented by an incomplete skull and mandible, together with some fragments of limb bones.

The Skull.—The skull is somewhat warped by earth pressure, the anterior portion of the frontal bone is missing, and the face is in many fragments. The occipital bone has a pronounced "bun." The sutures are

open, in particular the basi-occipital, indicating an immature individual. This is confirmed by the condition of the teeth in the mandible and in the maxillae fragments. The upper 2nd molars are erupted but not yet level with the 1st molar, and the 3rd molars are still in their crypts, with the crowns just pushing through the alveolar surface. In the mandible, which is fairly massive, the 3rd molars are just beginning to erupt.

The length and breadth of the skull can be estimated with some degree of accuracy giving the following figures:—

202 mm.?, 138 mm.?, with an index of 68·31.

The mandible, although reasonably complete, is too crushed and warped for accurate measurements.

The Skeleton.—This is represented by shaft fragments of one femur, tibia and humerus, together with a fragmentary scapula. No measurements are possible on any of these fragments, but their massiveness confirms the view based on the skull and mandible that the sex is male.

H.H. 6 may safely be regarded as an immature male.

[*H.H.* 7, 8, 9.—These three individuals belong to the intrusive Iron Age burial pits and not to the series under consideration.]

No. H.H. 10.

This individual is represented by some skull fragments, a few teeth, and some fragmentary limb bones. It is probably an elderly female, but there is insufficient material for any degree of certainty.

The Skull.—This is represented by a part of the occipital, parts of both temporals, a part of the left parietal, and a number of small fragments.

The Teeth.—Five broken upper molars and three broken premolars are preserved. All exhibit an advanced degree of wear.

The Skeleton.—The preserved parts are: fragments of both femora shafts; fragments of both tibiae; a fragment of fibula, and a fragment of radius.

The only measurements possible are the pilastric diameters of the femora shafts, which are very small and slender:

	Pil. A.P.D.	Pil. T.D.	100 A.P.D./T.D.
R.	21	20	105
L.	21	20	105

The individual was probably a small, elderly female.

No. H.H. 11.

This individual is represented by a more or less complete skull and mandible and a number of fragmentary limb bones. It is probably a female of middle age.

The Skull.—The braincase is nearly complete, but both temporal bones are damaged and the occipital is missing. It is greatly warped. All the sutures are closed. A part of the face is missing, but the greater part of both maxillae with the palate are preserved. In spite of the warping, the length and breadth can be estimated with reasonable accuracy and give values of: length, 182·5; breadth, 127·5; index, 68·78. The basi-bregmatic height is 128, giving a length-height index of 70·13 and a breadth-height index of 95·70. These figures are very close to those of the East African prehistoric skull, Willey's Kopje, No. 3, but in other respects the two skulls do not compare at all closely.

The palate is rather deep and there is considerable subnasal prognathism.

The Mandible.—The right ascending ramus of the mandible is missing, having been broken immediately behind the 3rd molar, together with the left condyle. The left coronoid is deformed, apparently as a result of disease. The mandible is otherwise complete and the full dentition is present. The mental eminence is strongly developed for a female and is massive. The corpus of the mandible is only 20 mm. high at the mid-point of the 2nd molars and 33 mm. high at the symphysis, comparing closely to the type of mandible characteristic of the Elmenteitan race.

It should be noted that in the illustration of this skull an undue degree of prognathism is indicated. This is due to warping. The mandible is shown with the left condylar area in proper relation to the articular surface on the temporal bone, but owing to the warping this surface is about 10 mm. too far forward.

The Skeleton.—The following parts of the skeleton are preserved: the shafts of both femora, both tibiae, both humeri, and some fragments of the other limb bones, together with a very fragmentary clavicle. The pilastric diameters of the femora shafts are the only measurements which can be taken:—

	Pil. A.P.D.	Pil. T.D.	100 A.P.D./T.D.
R.	20	18	111·11
L.	18·5	16·5	112·12

Both the femora shafts and the fragments of other limb bone shafts are very slender and indicate a small individual, probably a female.

[*H.H.* 12, 13, 14, 15, 16, 17, 18, 19, 20.—These nine individuals belong to the later intrusive burials and not to the series under consideration.]

No. H.H. 21.

This individual is represented by a few skull fragments, a fragmentary mandible and some loose teeth, together with parts of limb bone shafts. It is adult, although not aged, and possibly female.

The Skull.—This is represented by two greatly damaged parietal bones.

The Mandible.—A small fragment of the left side is preserved, having the canine, both premolars, and the 1st and 2nd molars in position.

The Teeth.—In addition to the teeth in the mandible fragment, there are the following loose teeth: six upper molars, the crowns of three lower molars, the crowns of six premolars, and the crowns of three incisors. The third molars were fully erupted and had just begun to come into wear at the time of death, indicating an individual in early adult life.

The Skeleton.—The skeleton is represented by two femora shafts, two fragmentary tibia shafts, and three small fragments of other limb bones. All belong to a small, slenderly built individual. The pilastric diameters of the femora shafts are the only measurements possible:—

	Pil. A.P.D.	Pil. T.D.	100 A.P.D./T.D.
R.	25·5	20	127·5
L.	24	20	120

The individual is probably a young adult female, although the femora are slightly thicker than those of some of the other females in the series. Positive sexing is not possible on the available evidence.

No. H.H. 22.

This individual is represented by a more or less complete skull and mandible and a fragmentary skeleton. It is an adult female.

The Skull.—The skull is somewhat damaged but not greatly warped, and a reasonably accurate reconstruction has therefore been possible. The right side of the frontal and the basal part of the occipital are missing, in addition to a large part of the face. The maxillae, however, are preserved together with the palate. The teeth are only very slightly worn, but the sutures are almost completely closed so that a middle-aged or even elderly adult is indicated. Both external orbital angles are missing. The supra-orbital area is very weak and the superciliaries only slightly developed. The left mastoid, which is intact, is very small. The skull is long and narrow and of an entirely different type from H.H. 1, which is pentagoid and mesocephalic whereas H.H. 22 is ultra-dolichocephalic. Few measurements are possible. The length is 172 and the breadth 120, giving an index of 68·18. The basi-bregmatic height can only be estimated since the basion is missing, but it was certainly greater than the breadth, in the region of

126 mm., giving an estimated breadth-height index of 95·23 and a length-height index of 73·25. These figures compare closely with those for H.H. 11, and we are clearly dealing with a skull of the same type. Fortunately H.H. 22 is not warped.

In the maxillae fragments which comprise the greater part of the palate, all the molars, premolars, one canine, and the right lateral incisor are preserved. The alveolar region of the other incisors and canine is broken.

The Mandible.—The mandible is complete except for a small part of the corpus below the right premolars and the posterior portion of both ascending rami, including the condyles and coronoids. All the teeth are present except the left central incisor. The mandible is of the Elmenteitan type, the height of the corpus at the mid-point of the 2nd molars being 23 mm. and the height at the symphysis 31 mm. The mental eminence is well developed, but the mandible is slender and suggests a female.

The Teeth.—The teeth are scarcely worn, a curious feature in a skull in which the sutures are almost completely closed.

The Skeleton.—The preserved parts of the skeleton are: both femora shafts; both tibiae shafts; both humeri shafts; some small fragments of other limb bones, and a fragment of innominate bone. This fragment has the sciatic notch intact and is clearly that of a female, thus confirming the evidence of the skull and mandible.

The only measurements of the skeleton which are possible are the pilastric and platymeric diameters of the femora:—

	Plat. A.P.D.	Plat. T.D.	100 A.P.D./T.D.	Pil. A.P.D.	Pil. T.D.	100 A.P.D./T.D.
R.	..	..	..	24·5	19·5	125·63
L.	20	29	68·96	22	19	115·69

Similarly to the femora shafts, the other limb bone fragments indicate a small, slenderly built individual. The characters of the skull and skeleton indicate a female. The evidence as to age is somewhat contradictory, but a middle-aged adult is probably represented.

No. H.H. 23.

This individual is represented by a single tooth and a number of small fragments of several limb bones. Nothing whatever can be said about it.

[*H.H.* 24.—This individual belongs to the intrusive Iron Age burials and not to the series under consideration.]

No. H.H. 25.

This individual is represented by a few teeth and a very much damaged mandible fragment together with some small pieces of several limb bones. Nothing whatever can be said about it.

[*H.H.* 26 *and* 27.—These two individuals belong to the intrusive Iron Age burials and not to the series under consideration.]

No. H.H. 28.

This individual is represented by a damaged skull, a rather better preserved mandible, and a fragmentary skeleton. It is probably a young adult male.

The Skull.—The skull was very crushed and fragile, but enough was preserved for a reasonably accurate reconstruction to be made of the calvaria. The greater part of the face is missing. The sutures other than the basi-occipital are open. The mastoids are small, but larger than those of definite females in the series. The general form suggests a male, but not a muscular individual. The external orbital angle is slender. Only a small part of the maxillae are preserved, the right side containing three molars and the 2nd premolar and the left side the three molars only. The 3rd molars are fully erupted and just coming into wear. The skull as reconstructed is 178 mm. long and 138 mm. in breadth, with a basi-bregmatic height of 127 mm. All these measurements are subject to slight error due to the reconstruction, but can be regarded as very close to the true figures. The indices are: length-breadth, 77·52; length-height, 71·34; breadth-height, 108·66. These place the skull in the same general category as H.H. 1, but distinguish it from the ultra-dolichocephalic type represented by H.H. 22.

The Mandible.—The mandible is well preserved and practically undamaged. The only tooth missing is the right lateral incisor. For a male, which I believe this individual to be, the mandible is rather weak and taken alone would suggest a female. The corpus is 22 mm. high at the mid-point of the 2nd molars and 32 mm. at the symphysis (estimated). The ascending rami are short and very wide, with a minimum width of 40 mm. The mental eminence is weakly developed. The teeth are small, but in no way peculiar. The 3rd molars were just coming into wear at death.

The Skeleton.—The following parts of the skeleton are preserved: both femora shafts; both tibiae shafts; both humeri shafts; fragments of the shafts of both fibulae, radii, ulnae and clavicles, together with parts of both scapulae and of one innominate bone with the sciatic notch intact. The form of this is intermediate between male and female, but suggests the former rather than the latter. The only measurements possible are on the femora shafts, which also indicate a weakly developed male:—

	Pil. A.P.D.	Pil. T.D.	100 A.P.D./T.D.
R.	22	19	115·69
L.	22	19	115·69

The estimated length of the right femur, which is the more complete of the two, is *circa* 415 mm.

On all the available evidence one is led to the conclusion that this individual was probably a poorly developed male, although it might possibly be a female.

[*H.H.* 29 *and* 30.—These two individuals belong to the intrusive Iron Age burials and not to the series at present under consideration.]

No. H.H. 31.

This individual is represented by a few small fragments of the skull and mandible and parts of the skeleton. It is probably a male of middle age.

The Skull.—This consists of a few fragments of the frontal, parietal, and temporal bones, together with a part of the right maxilla containing one premolar.

The Mandible.—There are two small fragments containing no teeth.

The Teeth.—Besides the one premolar in the maxilla fragment, the crown of a lower canine is preserved. Both teeth show a medium state of wear and suggest a middle age when compared with the teeth of the more complete and more determinate skulls in the series.

The Skeleton.—This is represented by a large part of the left femur shaft, a fragment of one humerus and a few other indeterminate shaft fragments. The femur shaft is very massive compared with others in the series and is almost certainly male. The pilastric diameters and index are as follows: A.P.D. 31, T.D. 25, Index 124.

The individual is almost certainly a male of middle age, judged on the massiveness of the femur and the wear of the two teeth.

No. H.H. 32.

This individual is represented by nothing more than the crowns of nine teeth in a very advanced stage of wear.

The Teeth.—These consist of the damaged crowns of three lower molars, three lower premolars, and three lower incisors.

Nothing can be said of the sex of the individual, but it is clearly considerably aged.

No. H.H. 33.

This individual is not represented at all in the material available. A grave was found, but the remains in it were mere splinters of bone.

[*H.H.* 34 *and* 35.—These two individuals belong to the intrusive Iron Age burial pits and not to the series under consideration.]

No. H.H. 36.

This individual is represented by a fragmentary skull and mandible and some parts of the skeleton, all much damaged. It is probably an elderly female.

The Skull.—Most of the skull is preserved except for the face, the greater part of the occipital bone, and the whole of the sphenoid. The sutures are all in an advanced state of fusion. The brain case, of which a reasonable reconstruction has been made, is short and relatively broad. It belongs to the same general type as H.H. 1, and not to the type represented by H.H. 6. The forehead is smooth and the external orbital angles very slender, giving the general impression of a female skull. The length as reconstructed is 169 mm., and may have been 1 or 2 milimetres more; the breadth is 134 mm., giving an index of 79·29. If the reconstruction is 2 mm. in excess of the original the index would become 78·3. It is certainly not under that figure. The post-orbital and minimum frontal breadth are both 99 mm.

The Mandible.—Both the ascending rami of the mandible are missing, but otherwise it is very little damaged. On the left side all three molars are present. The first premolar, the canine and both incisors are represented by roots in their sockets. The crowns of these teeth were not broken, but have been worn down until the whole of the enamel has disappeared. The 2nd premolar was lost in life, probably as the result of a severe abcess affecting the alveolar margin in that region. On the right side the 1st molar is preserved, together with the roots of the canine and of the lateral incisor, which are in the same condition as those on the left side. Immediately behind the 1st molar the alveolar border is pierced by a round hole, apparently due to a very severe abcess. The alveolar border in the region of the symphysis and also the mental eminence are broken away.

The Teeth.—The teeth are considerably worn, indicating a fairly advanced age, which is confirmed by the closed and much fused sutures of the skull.

The Skeleton.—Such' parts of the skeleton as are preserved are very much damaged, but part of the shaft of a tibia and a fragment of humerus are recognisable. No measurements are possible.

On the available evidence this individual may be regarded as an elderly female.

No. H.H. 37.

This individual is represented by four skull fragments, six teeth, and a few parts of the skeleton. It is probably an adult male.

The Skull.—These fragments are so corroded and weathered that they cannot be identified.

The Teeth.—These consist of 1 lower molar, 2 lower canines, 2 lower premolars, and 1 incisor, probably lower. All exhibit a certain amount of wear.

The Skeleton.—This is represented by two massive femora shafts, a fragment of humerus shaft, a fragment of tibia shaft, and some indeterminate shaft fragments. The pilastric diameters of the femora are the only measurements which can be taken:—

	Pil. A.P.D.	Pil. T.D.	100 A.P.D/T.D.
R.	33	24	137·5
L.	34	25	136

On the evidence available this individual must be regarded as a male, since none of the known females in the series have such massive femora shafts. The teeth indicate an adult.

No. H.H. 38.

This individual is represented by some fragments of the skull and mandible and a few fragments of the skeleton. It is probably a young female, but this is far from certain.

The Skull.—This is represented by parts of both temporal bones, part of the occipital and a number of very small fragments.

The Mandible.—The left side of the mandible is fairly complete, except for the condyle and coronoid which are broken away. On the right side, the whole of the ascending ramus is missing. The left half of the mandible contains the three molars and the 2nd premolar. On the right side the three molars are also present. The 3rd molars are fully erupted and just coming into wear. The symphysis and the area to the right of it is badly damaged. The mandible is lightly built and suggests a female.

The Teeth.—The teeth in the mandible are small and hardly worn at all. In addition, there is one loose upper right molar.

The Skeleton.—The following parts of the skeleton are preserved: fragments of both femora shafts, fragments of both tibiae, fragments of both humeri, and a number of small indeterminate shaft fragments. The pilastric diameters of the femora are the only measurements which can be taken:—

	Pil. A.P.D.	Pil. T.D.	100 A.P.D./T.D.
R.	19·5	21	92·85
L.	19·5	21	92·85

These femora show the rare phenomenon of an anterior-posterior pilastric measurement smaller than the transverse measurement.

The individual may be regarded as a young female, but it is just possible that it is an abnormal male.

Mound E, Nos. 1 *and* 2.

These two individuals were buried in a single grave, the bones were very fragmentary, No. 1 being the better preserved. It is represented by a large skull fragment and mandible, while a number of small skull fragments and some loose teeth represent No. 2. Some limb bone shaft fragments belonging to both individuals are also preserved. No. 1 was an adolescent with the third molars unerupted, while No. 2 was probably a young female.

The Skulls.—The large skull fragment representing No. 1 consists of the greater part of the occipital, about half the right parietal, and a part of the right temporal with the mastoid and auricular orifice intact. The sutures are open, and this fragment probably belongs to a young adult. The remaining fragments are greatly corroded by acids in the soil, but they include parts of the parietals and of one temporal.

The Mandible of No. 1.—This is small and slenderly built, with the three left molars, both premolars, the canine, and the left lateral incisor in position. On the right side the 2nd and 3rd molars are present. In the region of the 1st right molar and the right premolars the alveolar area shows considerable absorption, and these teeth were clearly lost a considerable time before death. The root sockets of the right canine and both incisors show that these teeth were lost after death. This also applies to the left central incisor. All the teeth show a certain amount of wear, especially the 1st molars. Even the 3rd molars are slightly worn, indicating a young adult.

Both the right molars and the left 3rd molars have a mass of tartar adhering to them on the buccal aspect. (A similar accretion of tartar is only known on one other prehistoric skull from East Africa, that of Nakuru IX from the Nakuru Burial Site.)

The skull fragment and the size of the mandible suggest that this individual was a female and the teeth indicate a young adult.

The Loose Teeth.—These comprise: (1) three upper molars in a similar state of wear to the molars in the mandible and probably belonging to the same individual; (2) the crowns of two lower third molars, unerupted and belonging to an adolescent; (3) three upper and one lower damaged premolars; (4) one lower and two upper canines, damaged; (5) one lower incisor; (6) four upper incisors which from their state of wear probably belong to the same individual as the mandible; (7) one lower left central incisor.

The Skeletons.—These are represented by parts of three femora shafts, parts of three tibiae shafts, two humeri fragments, two radius fragments, one ulna fragment, and a very small part of a female innominate bone belonging to No. 1. The only bones on which any measurements can be taken are the two better preserved femora shafts which belong to No. 1 and which have pilastric diameters and indices as follows:—

Pil. A.P.D.	Pil. T.D.	100 A.P.D./T.D.
R. . 21	20	105
L. . 22·5	20	112·5

Such evidence as there is suggests that the individuals in this dual burial were a young adult female (No. 1) and an adolescent of indeterminate sex (No. 2).

Summary and Conclusions on the Neolithic Series.

It is unfortunate that from what was potentially such a long series of Neolithic skulls, so few exist which are sufficiently well preserved to make accurate reconstruction possible.

The seven skulls which are to some extent measureable fall into two distinct groups. One of these, comprising skulls H.H. 1 (female), H.H. 28 (male), H.H. 36 (female), is a mesocephalic group with markedly pentagoid skulls. This group seems to stand very close to the second racial element represented in the Mesolithic skulls from Bromhead's Site, Elmenteita, by Elmenteita F1 (female) and Elmenteita C (male). The following comparison of indices shows this clearly:—

	100 B/L.	100 H/L.	100 B/H.
Elmenteita C ♂	76·36	73·7	103·89
Hyrax Hill 28 ♂ . .	77·52	71·34	106·23
Elmenteita F1 ♀ . . .	80·44	71·26	112·90
Hyrax Hill 1 ♀ . . .	77·08	67·27	114·75
Hyrax Hill 36 ♀ . . .	79·29	..	..

The second group at Hyrax Hill comprises skulls H.H. 2 (male), H.H. 6 (male), H.H. 11 (female), H.H. 22 (female). This group is very dolichocephalic and has marked similarities to skulls from a number of East African sites belonging to different periods of the Stone Age.

This type occurs at Gamble's Cave with a late Aurignacian stage of culture, at Bromhead's Site, Elmenteita, with a Mesolithic culture, at Nakuru Burial Site and at Willey's Kopje with the Gumban B and Gumban A Variants of the Stone Bowl Culture.

The following table demonstrates the comparison:—

	100 B/L.	100 H/L.	100 B/H.
Gamble's Cave No. 4 ♂ .	71·00	72·00	97·5
Elmenteita A ♂ . . .	67·45	69·21	98·94
Elmenteita D ♀ . . .	71·74	75·41	95·65
Nakuru IX ♂ . . .	69·25	71·12	97·36
Willey's Kopje III ♂ . .	67·16	69·83	95·71
Hyrax Hill 2 ♂ . . .	72·98	73·74	98·95
Hyrax Hill 6 ♂ . . .	68·31	..	..
Hyrax Hill 11 ♀ . . .	68·78	70·13	95·70
Hyrax Hill 22 ♀ . . .	68·18	73·25	95·23

The above table shows that the Hyrax Hill male skull H.H. 2 stands closest (on such data as are available, which are certainly meagre) to the late Upper Kenya Aurignacian skull, Gamble's Cave No. 4, while the females H.H. 11 and 22 in the Hyrax Hill series stand closest to the skull Nakuru IX which belongs to the Gumban B phase of the Neolithic.

It is most unfortunate that there is not a single skull in the whole Hyrax Hill series in which the face is intact. This means that we have no exact idea as to the nasal or orbital indices or the facial height and breadth.

Conclusions.—From the available evidence it would seem that at Hyrax Hill we are dealing with the same racial elements as are found at Bromhead's Site, Elmenteita, with a Mesolithic stage of culture. One of these elements is an ultra-dolichocephalic race which is present in the East African Stone Age population from Aurignacian times to the end of the Neolithic.

The second racial type is not so far known from any site earlier than the Mesolithic. It is mesocephalic, verging on brachycephalic, and is characterised by pentagoid skulls. This race seems to have been of small stature and shows marked prognathism. (See as examples F1 from the Elmenteitan series and H.H. 1 from Hyrax Hill.)

There is good reason to believe that both types are represented in the long series of skeletal material from the Neolithic site at the Njoro River Cave, which is as yet unpublished. It is to be hoped that when this series is studied it will be possible to say much more about these two types than is justifiable at present on the scanty material available.

2. Notes on the Skulls and Skeletons from the Iron Age Burial Pits.

Nos. H.H. 7, 8, 9, 12, *and* 13.

These five individuals were buried in the pit A2. Most of the bones of the skeletons and of the skulls were in such a crushed and powdery condition as to be unpreservable.

The preserved parts of these five individuals consist of: (1) the fragmentary skull and mandible of No. 9, (2) fragmentary femora shafts of Nos. 7, 8, 9, and 12, and (3) a quantity of shaft fragments of other limb bones, none of which are measurable. All the individuals appear to have been heavily built and were probably males, in particular No. 9, which is almost certainly a male.

Skull H.H. 9.—The greater part of the skull is preserved, but the different fragments are so warped that reconstruction is not possible. The preserved parts include the frontal, parts of both parietals, both temporals, the greater part of the occipital (damaged), the maxillae (damaged), together with a number of small fragments. The maxillae fragments include most of the

palatal area, all the molars and premolars as well as the right canine and the right incisors. The left incisors and left canine have been lost since death. The 3rd molars are fully erupted, but none of the teeth are much worn and the individual was therefore probably a young adult.

The Mandible of H.H. 9.—This is greatly crushed and is also somewhat warped, but the left side is almost intact. The greater part of the right ascending ramus is missing. All the molars and the 2nd premolars are preserved, but the other teeth are missing. The alveolar border is damaged in the region of the symphysis, but there are indications that the central incisors had been extracted in early life, so that the alveolar margin had fused and assumed a condition often seen in mandibles of modern natives who extract the incisors in early life.

The corpus of the mandible is almost the same height at the 2nd molars as at the symphysis, and the ascending ramus is set much more nearly at right angles to the corpus than in any of the mandibles in the Neolithic series. The coronoid process is high, forming a deep incisura very unlike the form seen in the Neolithic series.

The Femora Shafts of Nos. 7, 8, 9, *and* 12.—The following are the only measurements possible:—

	Pil. A.P.D.	Pil. T.D.	100 A.P.D./T.D.
No. 7, L.	35	29	120·69
No. 8, L.	30	26	115·38
No. 9, R.	26	24	108·33
L.	25	23	108·69
No. 12, R.	33	27	122·22
	32	27	114·81

Since the femora shafts of No. 9, which the skull and mandible strongly suggest are male, are less massive than those of Nos. 7, 8, and 12, it is likely that these are also males. Nothing can be said of No. 13.

No. H.H. 14.

This individual was buried in the same pit as No. 20 (A3). The bones and skull were in such a condition that all that could be saved, even with the use of shellac, was the left femur shaft, of which the pilastric diameters are as follows:—

	Pil. A.P.D.	Pil. T.D.	100 A.P.D./T.D.
L.	33	27	122·22

The size of the shaft suggests a strongly built male.

No. H.H. 15.

This individual, which was alone in Pit A4, and not associated with any other remains, is represented by a very crushed and fragmentary skull and a few teeth. The limb bones were in a powdery condition. The skull fragments are very thin and the few teeth preserved indicate a child. These consist of one upper milk molar, one lower milk molar, the crown of one unerupted 1st lower molar, and the crowns of two canines, neither of which was erupted.

Nos. H.H. 16, 17, *and* 18.

These three individuals were buried in Pit A5. No. 16 is the best preserved of all the Iron Age skeletons and is represented by a skull, mandible, and fragmentary skeleton. No. 17 was in a very fragmentary condition and the only preserved parts are the two femora shafts. No. 18 is represented by a crushed skull and mandible and a fragmentary skeleton.

Skull H.H. 16.—This is an unusually well-preserved skull for the series, the missing parts are: the squamous portion of the left temporal, a part of the basi-occipital, both malars, and the greater part of the maxillae. The sutures are open, but the third molars were fully erupted and only slightly worn. The skull is large and massive and exceptionally low crowned. The superciliary region has strongly developed ridges, but the supra-orbital ridges are very small and the external orbital angles are weak. The palate, a large part of which is intact, is deep, recalling that of Nakuru IX. The mastoids are small for so massive a skull. The maxillae carry all three molars, and both premolars on the left side and the second and third molars on the right side. The rest of the alveolar rim is broken away.

All the indications point to this being the skull of a young adult male, which is supported by the evidence of the fragmentary skeleton.

The Mandible.—This is very well preserved, the only missing parts being the condyles and the tips of the coronoids, together with the alveolar margins of both ascending rami. The whole mandible is massively built, and the height at the second molars is markedly less than at the symphysis, resembling in this the type of Elmenteita A and some of the Neolithic mandibles.

All the teeth are present except the two central incisors, which appear to have been extracted at a very early age since there is no gap in the place that these teeth should have been, but a shifting of the other teeth so that the gap is closed and the canines occupy the positions of the lateral incisors which, in turn, are in the positions of the central incisors. This condition is commonly seen in a proportion of the mandibles of modern native tribes in East Africa who practise the custom of extracting the central incisors. It

is usually due to the teeth being extracted at a very early age, as soon as the permanent teeth have replaced the milk dentition.

The following are the measurements of the skull and mandible. (*Note.*—Craniophore measurements cannot be taken owing to the fact that the lower margins of the orbits are missing, and there is no way of fixing the skull in the Frankfurt plane.)

L	197 mm.	S2	130
L′	..	S3	112·5
B	137·5	S′3	92·5
B1	100·5	U	544
B2	100·5	EH	17·5
B3	112		
H′	120·5	100 B/L	69·28
H	..	100 H′/L	60·65
OH	..	100 B/H′	114·11
LB	105		
Q	..		
Q′	293		
S	367·5		
S1	125		

None of the other skull measurements can be taken with any accuracy.

The Mandible.—The following measurements can be taken:—

W2	78	m2p1	30
H	38·5	m2h	29·5
zz	47		
G′2	38·5		

The Skeleton.—This is represented by the following parts: both femora shafts; both tibiae shafts; parts of both humeri; fragments of radii, ulnae, fibulae, and of one clavicle. With the exception of the femora shafts, all the bones are too crushed and distorted for measurements to be possible. All the bones indicate a massive individual.

The following are the pilastric diameters of H.H. 16 and of H.H. 17, the femora shafts being the only parts of H.H. 17 to be preserved:—

	A.P.D.	T.D.	100 A.P.D./T.D.
16 R.	33·5	26	128·84
16 L.	34	27	125·92
17 R.	37·5	25	150·00
17 L.	36	27	133·33

H.H. 17.—As will be seen from the above femora shaft measurements, this is a very large individual with unusually developed pilasters.

No. H.H. 18.

This individual is represented by a crushed skull with part of the palate, a mandible in similar condition, and a fragmentary skeleton. The skull is so crushed that little can be said about it save that it was thick-walled. Both upper and lower third molars are erupted, but little worn, indicating a young adult. The mandible, although crushed, is sufficiently complete for it to be stated that the central incisors had been extracted early in life. The gap thus formed having nearly closed up.

The Skeleton.—The skeleton is represented by the shafts of the femora, tibiae, and humeri, and a number of other fragments. The only measurements which can be taken are the pilastric diameters of the femora:—

	Pil. A.P.D.	Pil. T.D.	100 A.P.D./T.D.
R.	30	22	136·36
L.	29	21	138·09

This individual is probably a young adult male.

No. H.H. 19.

All the bones of this individual, which was by itself in Pit A6, were too crushed and fragmentary to be preserved except for a few teeth which show a greater degree of wear than any others in the series and probably indicate a middle aged individual.

No. H.H. 20.

This individual, which was in the same pit as H.H. 14 (A3), but in a part which was excavated later, is represented by a fragmentary mandible, some very broken parts of the skull, and a fragmentary skeleton.

The Mandible.—The left half of the mandible is practically intact, but the right half is badly crushed and a part of it is missing. The left half contains all three molars and both premolars as well as the roots of the canine and lateral inçisor. These two teeth are in the positions normally occupied by the lateral and central incisor, showing that the central incisors were probably extracted in early life, as in the other mandibles in the series. The molars and premolars show a considerable degree of wear, suggesting that death took place during middle age.

The Skeleton.—This is represented by shaft fragments of femora, tibiae, humeri, and many other indeterminate fragments. All are too crushed to be measureable.

No. H.H. 24.

This individual is represented by a few small skull fragments, nothing whatever can be said about them.

Nos. H.H. 26 *and* 27.

These two individuals were together in Pit A7, they are represented by two crushed and fragmentary skulls, a number of broken teeth, and some very crushed limb bone shafts. No. 27 had a very thick skull and was more massive than No. 26, but both are too damaged for any measurements to be taken. This also applies to the limb bones.

Nos. H.H. 29 *and* 30.

These two individuals were together in Pit A8. They are represented by one nearly complete but very crushed skull, with palate and mandible, and a second more fragmentary skull which, however, has most of the palate and a part of the mandible preserved. The skeletons are represented by numerous crushed fragments of limb bone shafts, among which the femora shafts of No. 30 are the only ones on which any measurements can be taken.

The Mandibles.—An examination of the two mandibles reveals that in No. 29 none of the incisors had been extracted, while in No. 30 it is clear that the two central incisors had been extracted at an early age so that the gap formed by their removal has been closed by the gradual sideways movement of the lateral incisors and canines.

Both individuals were young adults, with the 3rd molars fully erupted but only very slightly worn. The size of the skull and mandible fragments and of the limb bones suggests that the sex is male.

The femora shafts of H.H. 30 give the following pilastric diameter measurements:—

	A.P.D.	T.D.	100 A.P.D./T.D.
R. .	31	24	129·16
L. .	30	26	115·38

Nos. H.H. 34 *and* 35.

These two individuals were together in Pit A9. No. 34 is represented by nothing more than a fragmentary palate and mandible and a few other skull fragments. All the limb bones were too crushed to be preserved. The mandible fragment of No. 34 shows that the two central incisors had been extracted in early life, but the gap had not fully closed. The 3rd molars were erupted but little worn, indicating a young adult. From the size of the fragments it is possible that the sex is male.

No. 35 is represented by a more complete, but very crushed skull and mandible and a few fragmentary limb bones, including the greater part of the left femur shaft, which is measurable.

The alveolar region of the mandible is broken away in the region of the

symphysis so that it is not possible to determine whether or not the central incisors had been extracted. The 3rd molars were erupted but little worn, indicating a young adult. The size of the preserved fragments suggests that the sex may have been male.

The pilastric diameters of the left femur shaft of No. 35 are as follows:—

	A.P.D.	T.D.	100 A.P.D./T.D.
L. .	30·5	27	112·96

Conclusions.

The one intact skull is of great interest on account of its size and low crown. It is very unfortunate that none of the other skulls are sufficiently intact to show whether this individual is typical of the whole group or an aberrant and atypical specimen.

With the exception of one child and the two middle-aged men, all the individuals would seem to be young adult males, a somewhat unusual circumstance, unless these burials represent the dead from a battle or from some other event which resulted in the death of a number of young men at about the same time.

Except in the case of the mandible of No. 29, whenever it is possible to examine the incisor region, the two lower central incisors are found to have been extracted at an early age: a custom common among certain living East African tribes, but also found in the late Neolithic remains from Willey's Kopje and the Makalia Burial Site, belonging to the Gumban A Variant of the Stone Bowl Culture.

All the limb bone fragments, excepting those of the child, No. 15, indicate massive and very muscular individuals. The average for all the pilastric indices is 121·99 on a series of fourteen femora, an extremely high and abnormal figure. The range is from 108·33 to 150·00.

It is not at all easy to determine the affinities of the one skull which is well preserved. In certain respects it stands nearer to the Willey's Kopje skulls than to any others, but the mandible has features of the Elmenteitan A type which are wholly unlike those from Willey's Kopje.

The condition of the bones in this series is "biscuity" and completely unmineralised, but nearly all the animal fats and gelatine have gone. The condition is not at all unlike that seen in the bones of Anglo-Saxon burials in England which have not been in chalk or clay soil.

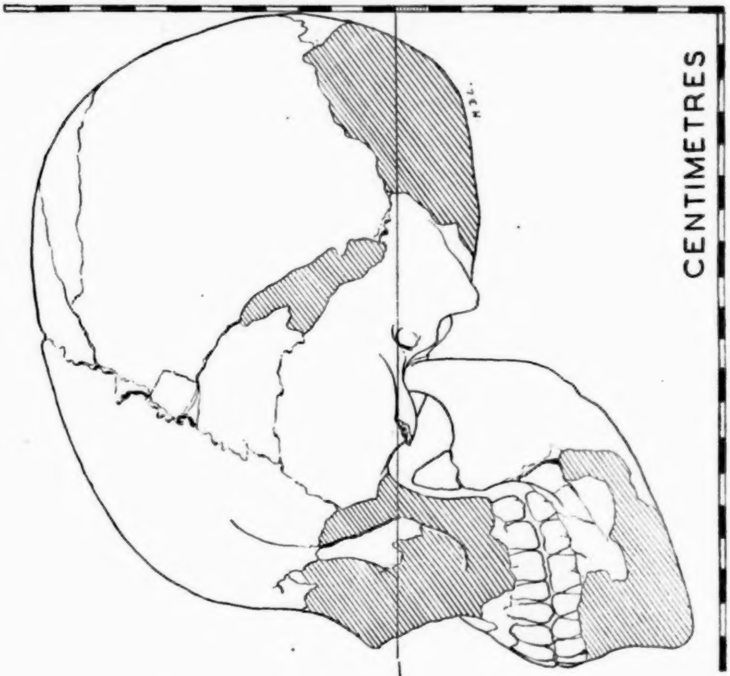


Fig. 26a.—Skull H.H. 1.

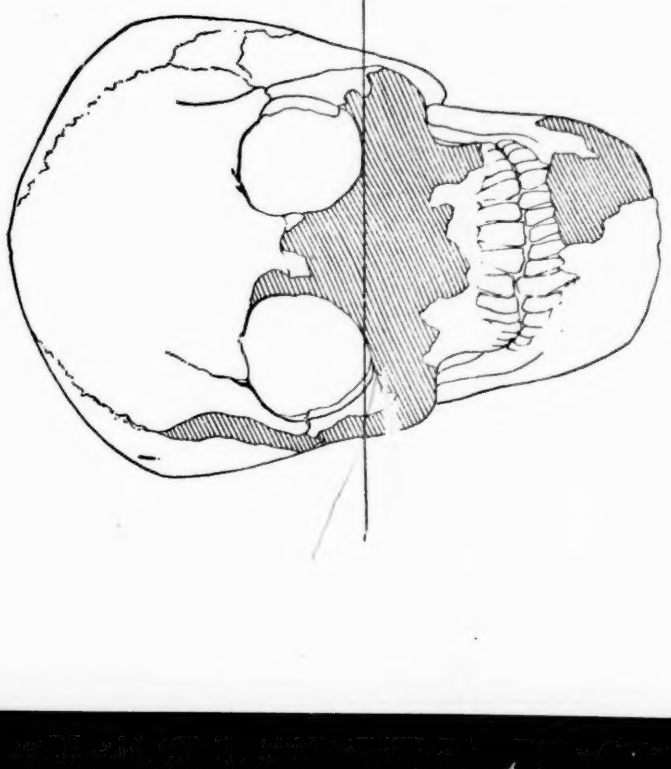


Fig. 26b.

Fig. 27A.—Skull H.H. 2.

Fig. 27B.

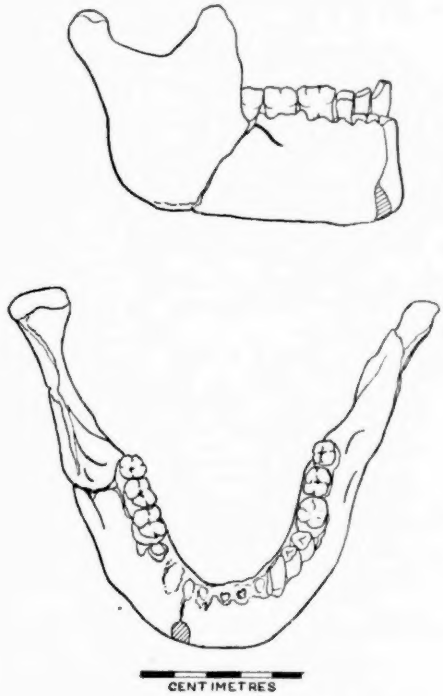


FIG. 28.—Mandible of H.H. 5.

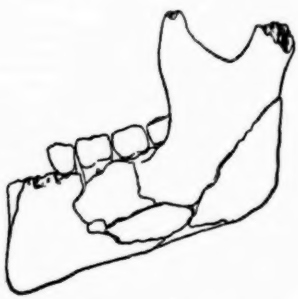


FIG. 34C.—Mandible of H.H. 9.

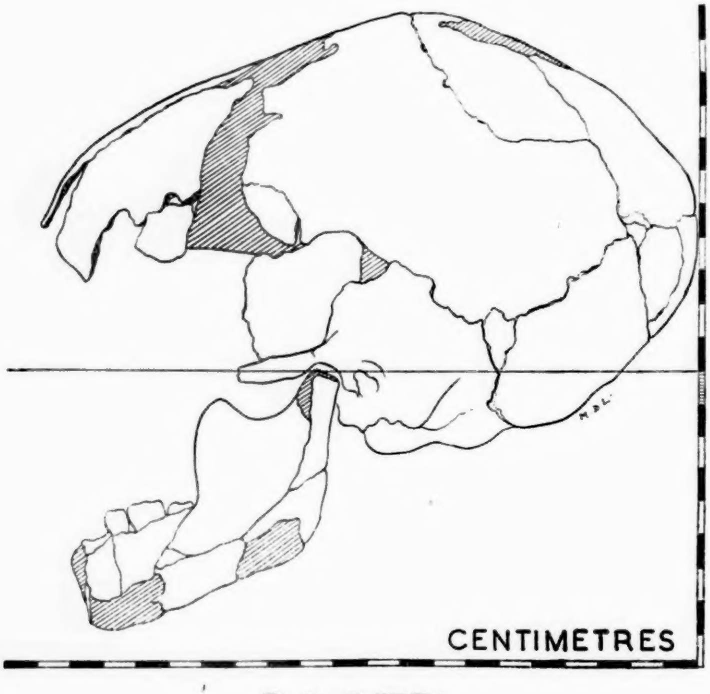


Fig. 29.—Skull H.H. 6.

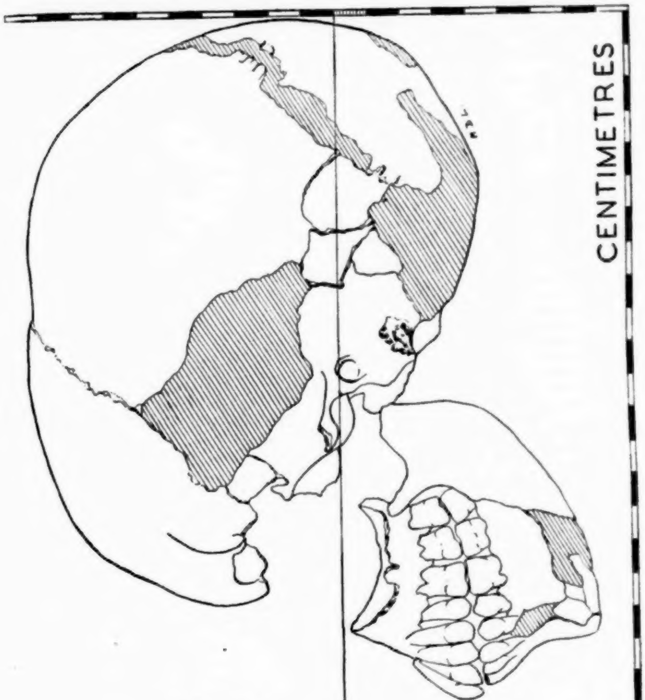


FIG. 30A.—Skull H.H. 11.

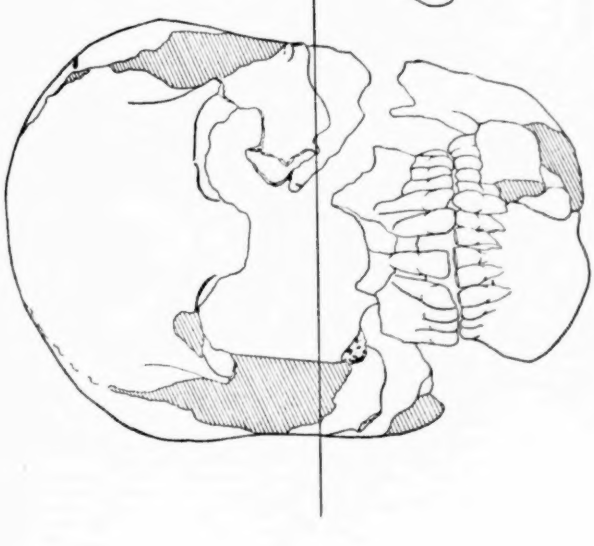


FIG. 30B.

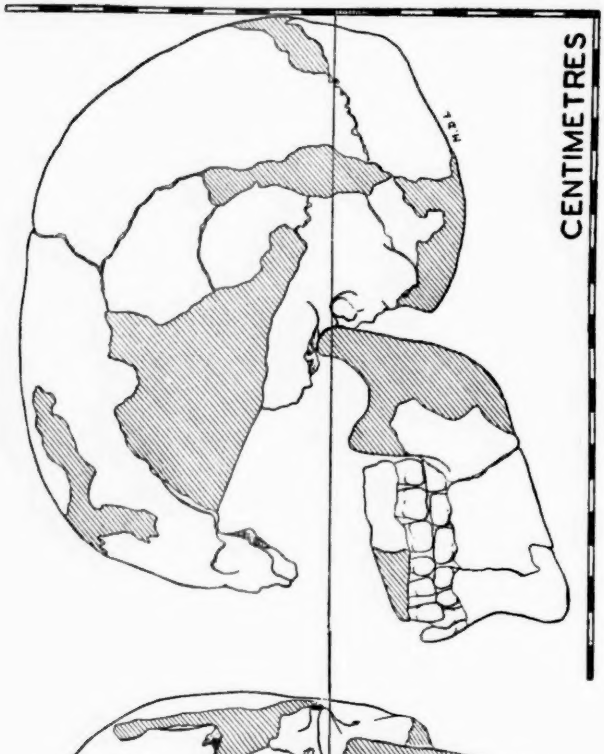


FIG. 31A.—Skull H.H. 22.

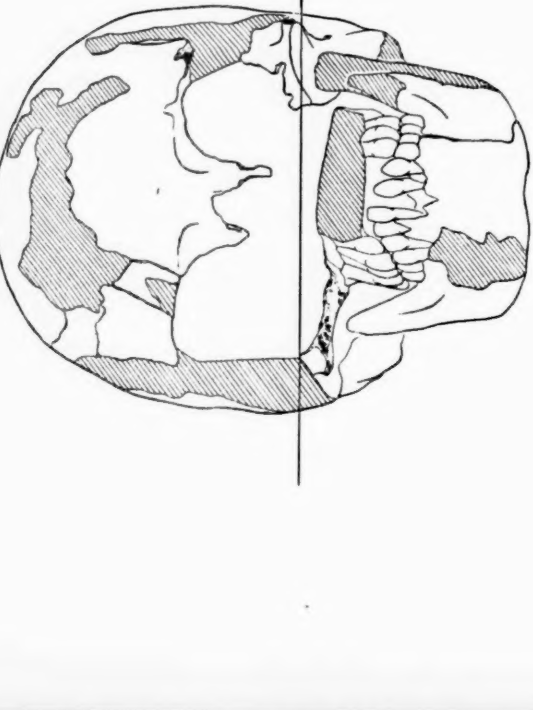


FIG. 31B.

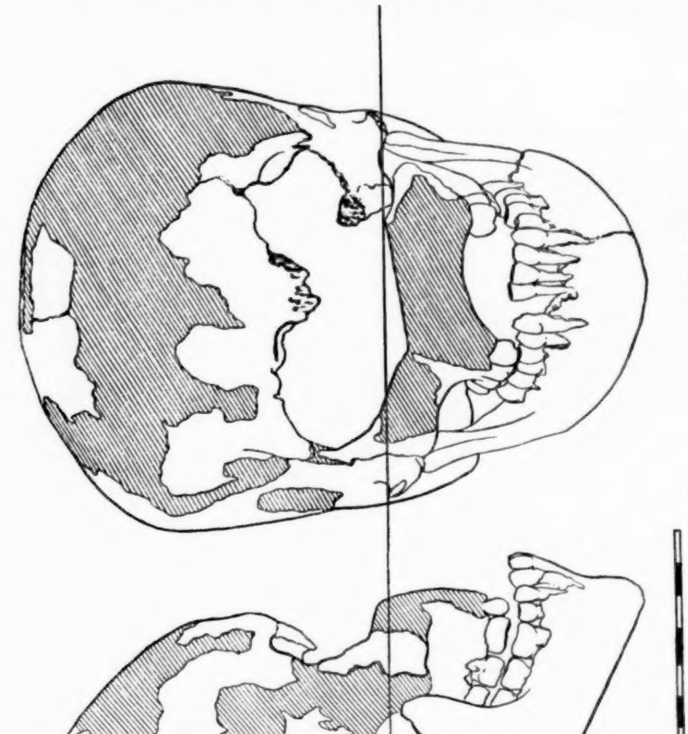


FIG. 32B.

FIG. 32A.—Skull H.H. 28.

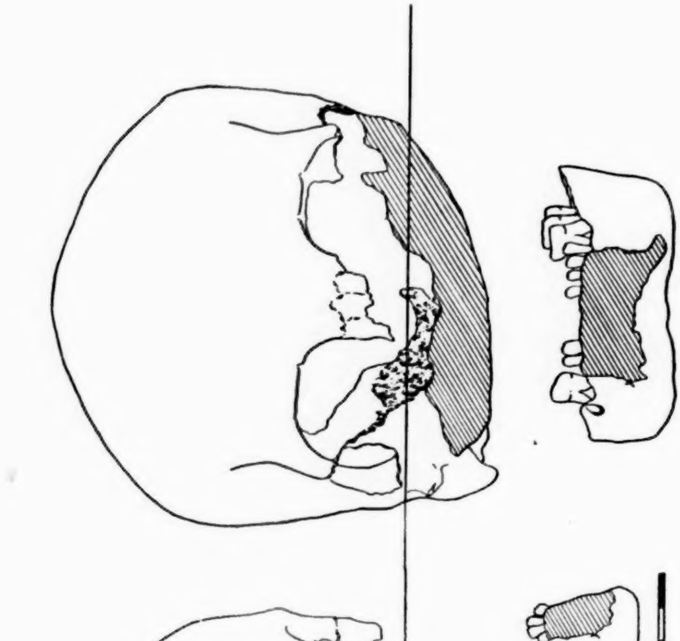


FIG. 33A.—Skull of H.H. 36.

FIG. 33B.

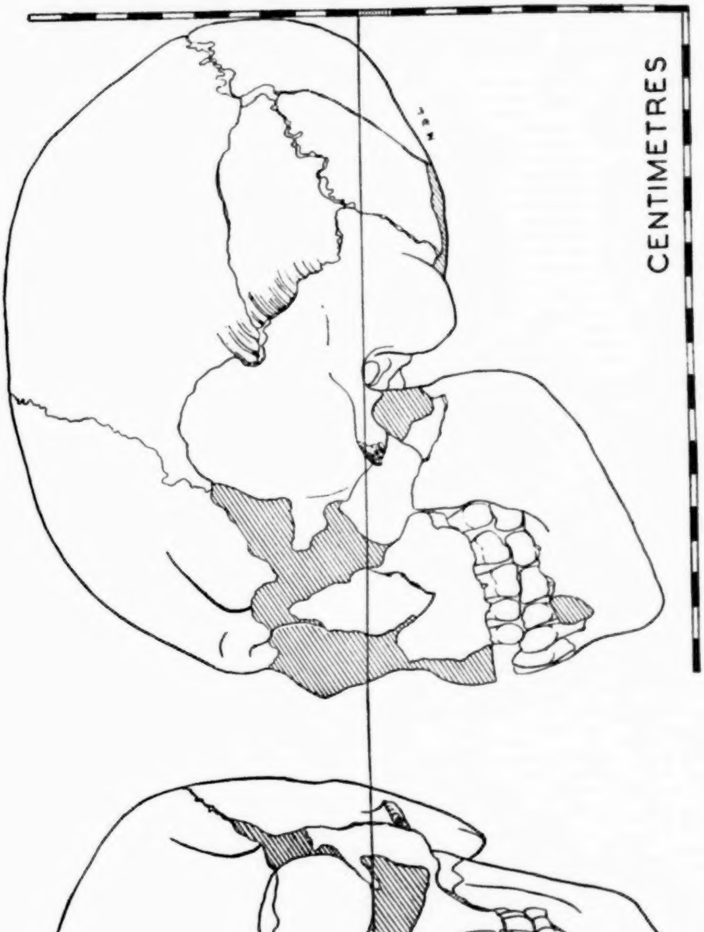


Fig. 34a.—Skull H.H. 16.

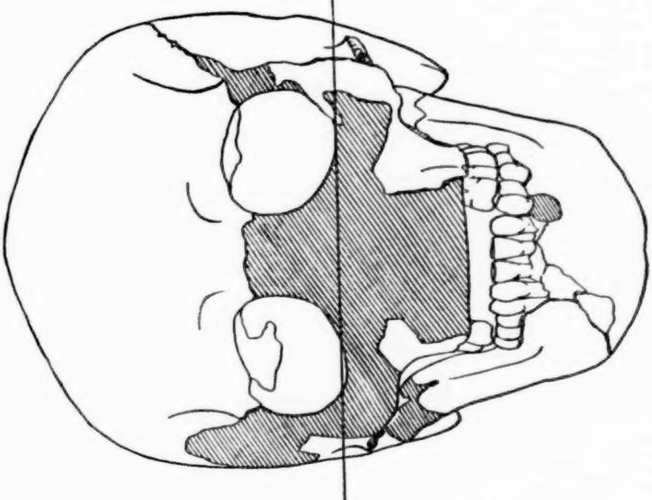


Fig. 34b.

APPENDIX.

NOTE ON THE INTERRELATIONSHIPS OF VARIOUS OBSIDIANS COLLECTED BY MRS. LEAKEY IN KENYA COLONY.

By P. M. Game, Assistant Keeper, Department of Mineralogy, British Museum (Natural History).

The obsidians sent by Mrs. Leakey from Kenya Colony included several specimens from each of the following localities:—

1. Prehistoric obsidian mine in the Njorowa Gorge, near Lake Naivasha.
2. Mt. Eburu.

3 and 4. Neolithic site at Hyrax Hill, Nakuru.

In order to investigate possible correspondences or differences between the four obsidians, the following determinations were made:—

1. Specific gravity.
2. Refractive index.
3. The specific refractivity (K) calculated from the above two values, the relationship being $K = \frac{n-1}{d}$ when n is the R.I. and d the specific gravity.
4. Thin sections of each type were examined with the microscope.

Evidence from the Pyhsical Properties of the Obsidians.

The values for the three properties enumerated above are best given in graphic form. In order to do this the diagrams used by Tilley (Min. Mag., March 1922, vol. xix, No. 96, pp. 282 and 283) have been employed, and are reproduced here in figs. 1 and 2. They are self-explanatory.

As regards the "grouping" of the obsidians when their three values are plotted on these two graphs, it will be apparent that Nos. 1 and 3 are close together in both, and that they fall within the "Rhyolite-obsidian" group as given by Tilley. Nos. 2 and 4 do not show such close correspondence but they appear to be naturally separated from Nos. 1 and 3, and to belong to the "Trachyte-obsidian" group.

The position of the No. 2 point is probably slightly in error, as it was found difficult to determine accurately the refractive index of this obsidian, because of the marked flow-structure which has produced long, turbid streaks of incipient crystallization.

The determined specific gravity of the glass will be somewhat too small in No. 3, which contains numerous air-bubble inclusions. Point 3 should therefore be a little lower and further to the right in fig. 1 and a little further to the right in fig. 2.

The determined physical properties seem, therefore, to indicate a similarity between Nos. 1 and 3 and not so marked a correspondence between Nos. 2 and 4. Also there appears to be a distinct separation between the two groups.

EVIDENCE FROM MICROSCOPIC EXAMINATION OF THIN SECTIONS.

The results of this examination are in general agreement with those obtained for the physical properties. It will be well to give a brief description of each type.

No. 1, *Njorowa Gorge Mine*.—An almost completely glassy rock, the only crystals being feldspar microlites. Irresolvable rod-like bodies also occur and probably represent the incipient crystallization of pyroxene. There is a well-marked flow-structure. The dark-coloured material forming parallel streaks in the glass is possibly altered riebeckite or other soda-rich amphibole.

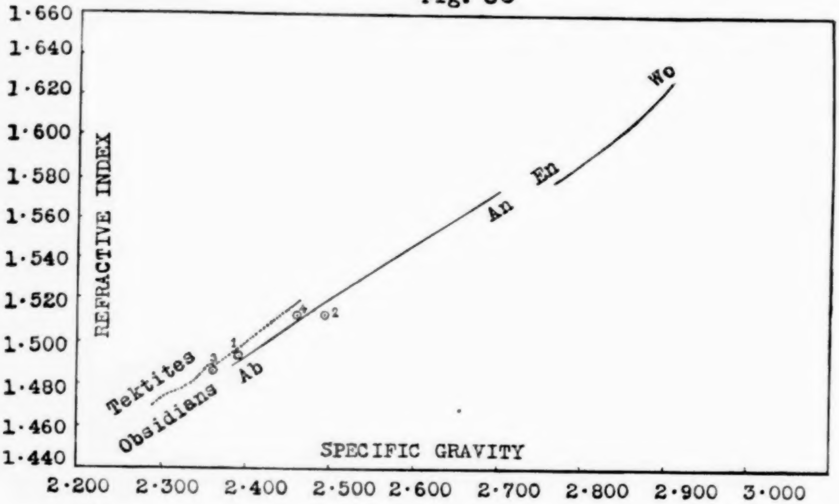
No. 3.—Since these fragments appeared to differ somewhat among themselves, two sections were cut from different pieces. The first section was that of an almost entirely glassy type, with extremely sparse and very minute crystals of pyroxene and feldspar. A flow structure is shown by rows of bubbles in the glass, each bubble being elongated in the flow direction. This section is closely similar to that of the Njorowa Gorge obsidian (No. 1). The second section shows a somewhat more advanced stage of crystallization. Feldspar and pyroxene crystals, though very sparse, are larger than in the first section. Also there are numerous extremely minute, idiomorphic octahedrons of magnetite and a few larger subidiomorphic crystals. Several small prisms of zircon occur and there are a few, dark yellowish-brown needles, which are probably cossyrite, up to 0·6 mm. in length, strongly pleochroic. The pyroxene has a clear grass-green colour but is not noticeably pleochroic. The extinction angle ($a^\wedge c$) is up to 43°. The mineral is not aegirine, therefore, but probably a diopsidic augite and it differs from the pyroxene of the other two obsidians, Nos. 2 and 4. A flow-structure is not prominent, but is nevertheless definitely shown.

No. 2, *Eburu*.—A dominantly, but not completely, glassy obsidian, the size and number of crystals being much greater than in either No. 1 or No. 3.

Feldspar (anorthoclase?) forms stumpy or elongated columns, which average 0·1 mm. in length. They show a rather strict parallelism of crystal length, and many are twinned so that they show a cruciform or forked relationship. They contain a few inclusions of pyroxene crystallites. Needles and rods of aegirine-augite, also about 0·1 mm. long, occasionally twice this length, are common, and show a marked parallelism. They are grass-green to yellow-green in colour and faintly pleochroic. The extinction angles, measured from the elongation direction (being, therefore, presumably $a^\wedge c$) are small—less than 20°. A flow-structure is rather marked; there are turbid streaks, elongated in the flow direction.

No. 4.—The slide of this obsidian shows a rather close resemblance to that of the preceding rock from Eburu. The crystals are the same, viz. potash-feldspar and a green pyroxene, which is either aegirine or aegirine-augite, but they are slightly larger and more numerous (*i.e.* the proportion of crystals to glass is greater). The pyroxene is slightly more pleochroic than the aegirine-augite of the previous rock, and the extinction angles are a little smaller, averaging about 11°. The feldspar crystals are twinned on the same law as those in the Eburu obsidian. They do not, however, show the marked parallel arrangement which was observed in that slide. In fact,

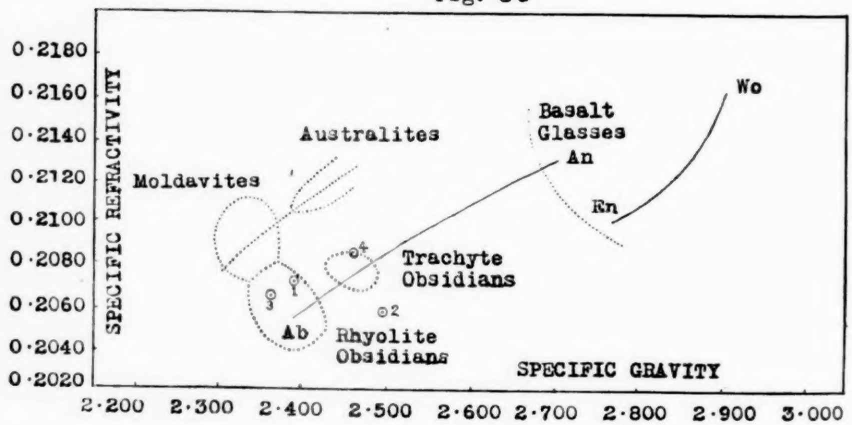
Fig. 35



1 = Njorowa Gorge Mine.
2 = Eburu.
3 = 3. } Hyrax Hill
4 = 4. }

Ab-An Albite-Anorthite Glasses
En-Wo $MgSiO_3$-$CaSiO_3$ Glasses

Fig. 36



flow-structure is not nearly so prominent in this obsidian, although it is quite evident on a macroscopic scale. Enormous numbers of irresolvable needles or hair-like crystallites (probably pyroxene) are crowded together in the glass, producing a felt-like appearance. They are not in parallel arrangement as in the preceding slide.

The differences between obsidians No. 4 and No. 2, briefly recapitulated, are that the latter is a more glassy type with somewhat smaller pyroxenes less rich in soda, and a more marked flow structure. In other respects the two types are closely similar, and are, in fact, a better "match" than Nos. 1 and 3, when considered from a purely petrological viewpoint. They differ from Nos. 1 and 3 in having a very much greater percentage of crystalline material and a more sodic pyroxene. Also they have not the zircon, cossyrite, or magnetite crystals common to No. 3. Finally the feldspar shows a type of twinning not present in that in Nos. 1 or 3.

Thus the petrological examination separates the obsidians into the same two groups as do their physical properties; although in the former comparison the correspondence is closer between Nos. 2 and 4 and in the latter between Nos. 1 and 3, the general deduction clearly seems to be that No. 3 was obtained from the same flow as No. 1 (Njorowa Gorge) and No. 4 from the same as No. 2 (Eburu).

Hyrax Hill from the south. The stone walls of the Iron Age settlement may be seen at the foot of the hill, behind the grass huts.

Mary D. Leakey. *Neill & Co., Ltd.*

The excavations at Site I. The Iron Age Enclosure B and Hut A may be seen on the left.

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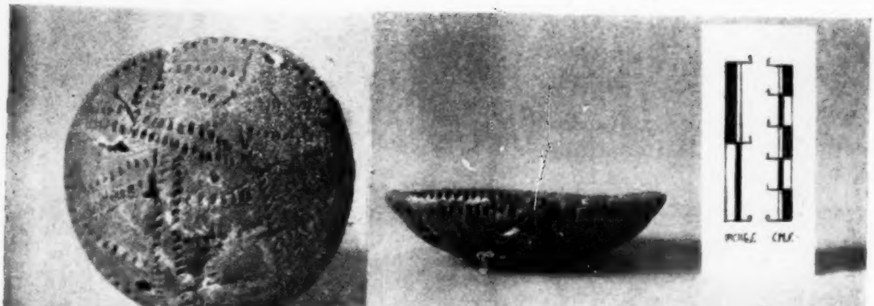

5

Reconstructed pots from the Neolithic occupation at Site I.

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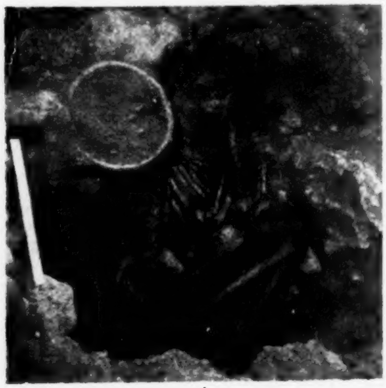

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THE CEMETERY.

1. The west face of Cutting III, looking south-east. The layer of beach pebbles overlain by the occupation level (layer 2) may be seen together with the boulder layer of the cemetery.
2. The boulder layer of the cemetery after the removal of the smaller stones and earth (Cutting III).
3. The west face of Cutting III, looking north-west. Skeleton H.H. 6 may be seen lying *in situ* on the undisturbed soil. The walls of the Iron Age Hut A are visible in the background.
4. Skeleton H.H. 1. The stone platter and the pestle can be seen *in situ* (Cutting Ix).
5. Skeleton H.H. 2 (Cutting Ix).
6. Skeleton H.H. 3 (Cutting Ie).

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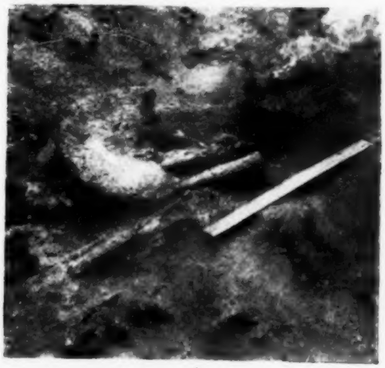

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THE CEMETERY.

1. The disarticulated remains of H.H. 4 superimposed on the articulated skeleton H.H. 5 (Cutting III).
2. Skeleton H.H. 5 (Cutting III).
3. Skeleton H.H. 6 (Cutting III).
4. Skeleton H.H. 10. The broken stone platter may be seen lying on the shafts of the limb bones (Cutting I).
5. The disarticulated skeleton H.H. 11. The unnatural relationship of the skull and limb bones can be clearly seen, together with the stone platter and pestle (Cutting I).
6. Skeleton H.H. 21, probably a reserved burial. The unusually well-made stone platter can be seen resting on the limb bones and the isolated humerus is visible in the right top corner of the photograph (Cutting IV).

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1 2 3 4 5 6

THE CEMETERY.

1. The partially excavated grave of H.H. 22. Portions of the skull and the stone platter may be seen inside the grave (Cutting IV).
2. Skeleton H.H. 22 with the stone platter (Cutting IV).
3. Skeleton H.H. 28 (Cutting V).
4. Skeleton H.H. 36. The inverted stone platter may be seen to the right of the body, which was not in a grave (Cutting IIIb).
5. The capstone of H.H. 38. The underlying grave, which contained the skeleton, is clearly visible together with the intervening earth layer (Cutting IIs).
6. Skeleton H.H. 38. The unusual extended position of the right arm may be seen together with the stone platter lying on the edge of the grave (Cutting IIs).

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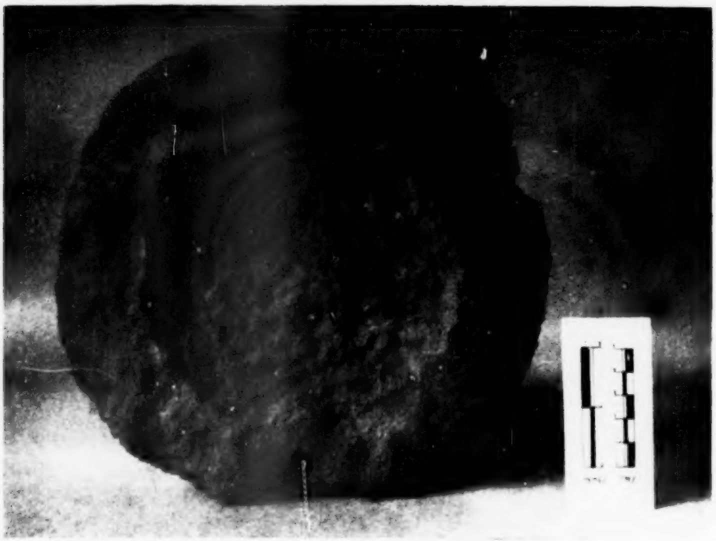
Mound "E."

1. Half the mound cleared to the level of large stones.
2. The dual interment in the central grave.



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1. Unfinished stone platter from Mound "E."
2. Stone platter S. 12 found with Skeleton No. 21.
3. Stone platter S. 1 found with Skeleton No. 1.

1

2

3

1. Hut C after excavation.
2. Pit A2. Skeletons 7 and 8.
3. Pit A3. Skull No. 9.

1

2

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1. Pit A3. Skeleton No. 20, showing the iron bracelet lying above the foot rule.
2. Pit A5. Skeletons 16 and 17, with No. 18 partly exposed.
3. Pit A5. Skeleton No. 18.
4. Pit A8. Skeletons Nos. 29 and 30.
5. Pit A9. Section through pit exposed in the north face of Cutting IX, also the limb bones of Skeleton No. 35.
6. Pit A9. Skeleton No. 35.

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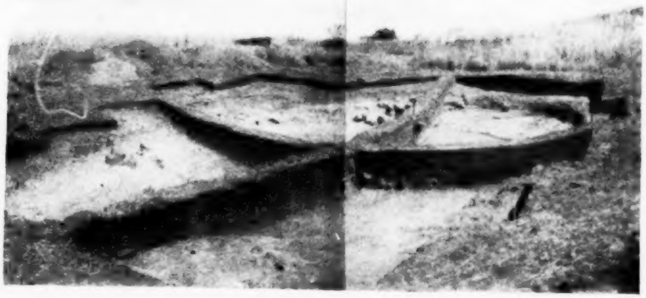

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The North-East Village.

1. Pit B after excavation, from the west.
2. Pit C part excavated with the cross-sections still standing, from the west.
3. Pit C after excavation, from the south-west.

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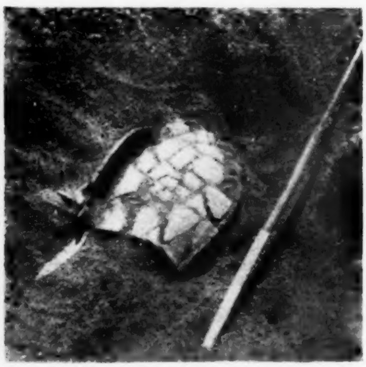

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Pottery from the North-East Village.

1. Globular pot with spout and impressed cord decoration, from Pit B.
2 and 3. Pots with spouts and handles from Pit B.
4. Two-handled jar from Midden A.
5. The two-handled jar lying *in situ*.
6. Lower grindstone from Cutting IX, Pit C.

1

2

Modern pit dwellings used by the Iraaq tribe, Tanganyika Territory.

1. House in occupation. The granary and the midden may be seen on the right.

2. Abandoned house with the roof supports still in position. Although not silted to the same degree as the North-East Village pits, the general form is entirely similar.

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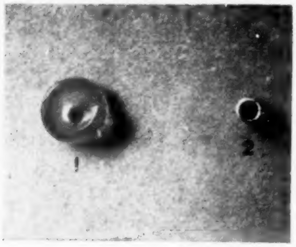

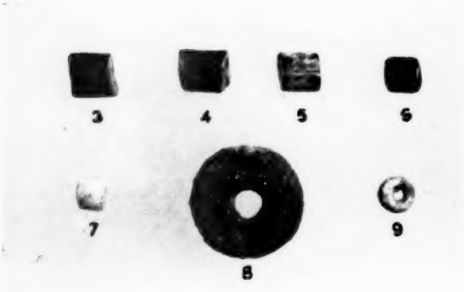

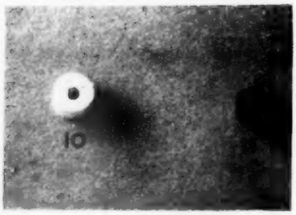

1–2. Beads from the Neolithic Cemetery.
3–9. Beads from the Iron Age Settlement.
10–11. Two beads from the North-East Village.

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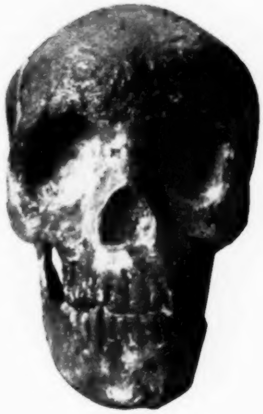
1



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1 and 2. Neolithic skull H.H. 1, side view and full face. (The facial area is reconstructed.)
3 and 4. Neolithic skull H.H. 28, side view and full face. (The facial area and a large part of the frontal bone are reconstructed.)
5 and 6. Iron Age skull H.H. 16, side view and full face. (The facial area is reconstructed.)

All the skulls are orientated as nearly as possible in the Frankfurt plane.

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TRANSACTIONS

OF THE

ROYAL SOCIETY OF SOUTH AFRICA.

VOL. XXX.

MINUTES OF PROCEEDINGS.

Anniversary Meeting.

The Anniversary Meeting of the Society was held on Wednesday, March 19, 1941, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. Crawford, was in the Chair.

Business:—

The Annual Report of the Honorary Secretary for 1940 was read and adopted.

The Annual Report of the Honorary Treasurer for 1940 was read and adopted.

The following were elected Officers and Council for 1941:—President, L. Crawford; Hon. Treasurer, R. W. James; Hon. General Secretary, A. J. H. Goodwin; Hon. Editor of Transactions, M. R. Levyns; Hon. Librarian, E. Newbery. Other Members: G. Arnold, W. F. Barker, A. Brown, E. L. Gill, J. Jackson, M. Rindl, L. Verwoerd, C. von Bonde, H. E. Wood.

Ordinary Meeting.

The Anniversary Meeting was followed by an Ordinary Meeting.

Business:—

The Minutes of the Ordinary Meeting of November 20, 1940, were read and passed.

The following were nominated to Membership of the Society:— Richard William Varder, proposed by A. Brown, seconded by

D. Burnett; Francis Cabu, proposed by E. L. Gill, seconded by A. J. H. Goodwin; John Asaraia Keen, proposed by M. R. Drennan, seconded by A. J. H. Goodwin; C. J. Molteno, proposed by E. Newbery, seconded by A. J. H. Goodwin; Alfred Leslie Payne, proposed by W. J. Talbot, seconded by A. J. H. Goodwin.

The incoming Treasurer, R. W. James, was duly empowered to act in the name of the Society in dealing with the following accounts:—

Post Office Savings Bank, Cape Town; Cape of Good Hope Savings Bank, Cape Town; Standard Bank of South Africa, Rondebosch; Rand Provident Building Society, Cape Town.

Communications:—

"N.P. Relations in Rough Lemon Seedlings," by J. W. Pont.

In young Rough Lemon trees no negative correlation between nitrogen and phosphorus could be observed in either the leaves, the stems, or the roots. A positive correlation between nitrogen and phosphorus existed in the roots only. Roots, stems, and leaves form distinct metabolic systems and it appears plausible to accept that fruits form a separate system.

"Colour Vision and Colour Discrimination among the Bechuana," by B. T. Squires (communicated by I. Schapera).

"Bubbles in Polyhedral Geodes from Swaziland," by E. D. Mountain.

"The Letaba Hot Spring," by L. E. Kent (communicated by S. H. Haughton).

"The *Hersiliidae* (*Araneae*) of South Africa," by R. H. N. Smithers.

A systematic survey of the family *Hersiliidae* (*Araneae*) of South Africa is presented, together with keys to the genera and species comprising the family. The description of two new species of *Tama* and biological notes on this genus are given. E. Simon's *Hersiliola australis* is discussed and additional characters facilitating the identification of this and other species of *Hersiliidae* are supplied, the epigynes of all species being figured.

"Abnormalities and Variations in the Vascular System of *Xenopus laevis*," by N. Millard (communicated by A. J. H. Goodwin).

Demonstration:—

"Paralysis in White Rats produced by a Rachitogenic Diet," by H. A. Shapiro.

Young white rats at 50–60 gms. were placed on Steenbock's rachitogenic diet No. 2965. After 21 days they developed severe rickets. This was demonstrated radiologically as well as by the line test.

When the animals were maintained on this diet for prolonged periods ranging from 6 to 17 weeks a progressive paralysis of the hind limbs developed. This began as an extensor weakness affecting the foot, and producing foot-drop. The paralysis then spread progressively until the

rat was unable to stand on its hind legs, and could only move by dragging itself along with the aid of its fore limbs. With well-developed paralysis there were signs of urinary and rectal incontinence, as well as priapism. The fore limbs were not affected.

The syndrome appears to be due to a cord lesion, and has been shown not to be due to any of the known vitamins, A, B_1, C, or E. α-tocopherol given at the stage of well-developed foot-drop did not arrest the progress of the lesion. The lesion is either due to a complication of severe rickets or to the absence of a hitherto unrecognised vitamin. The paralysis has been produced in 13 rats in different experiments on different occasions.

EXHIBITION.—"A Device for Supporting an Injured Leg during Conveyance on a Stretcher," by F. G. CAWSTON.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, April 16, 1941, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. Crawford, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of March 19, 1941, were passed.

The following were duly elected to Membership of the Society:—RICHARD WILLIAM VARDER, FRANCIS CABU, JOHN ASARAIA KEEN, C. J. MOLTENO, ALFRED LESLIE PAYNE.

MORNA MATHIAS, proposed by F. WALKER, seconded by A. R. E. WALKER, was nominated for election to Membership.

Marloth Memorial:—

The President announced that the sum of £200 had been received by the Society from the Cape Chemical and Technical Society. This sum represents the Marloth Memorial Fund, contributed in part by the Chemical Society, but mainly by subscription from Members and non-Members of that Society. Interest on the fund will be used to aid the publication of selected papers in such studies, mainly Chemical and Botanical, whose publication would be a fitting memorial to the late Dr. Marloth.

A medallion was projected, showing the heading which will appear above published papers so selected. The Chemical Society is bearing the cost of the design and the necessary block for printing.

Communications:—

"The Middle Stone Age of the Upper Caledon River Valley: The Modderpoort Culture," by B. D. MALAN (communicated by A. J. H. GOODWIN).

"The Associated Fauna and Cultures of the Vlakkraal Thermal Springs, O.F.S.," by L. H. Wells and B. D. Malan.

"Introduction à l'étude de l'Homme de Likasi," par F. Cabu.

"Report on the Likasi Skeleton," by M. R. Drennan.

Lecture.—"Some Geographical Factors in South-Eastern Europe," by W. J. Talbot.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, May 21, 1941, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. Crawford, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of April 16, 1941, were passed.

Mrs. Morna Mathias was elected to Membership of the Society.

The President announced that all prices of back numbers of both the Philosophical Society and of the Royal Society of South Africa Transactions are suspended for the duration of the war, and until further notice. Any person or body needing copies must make written application through the Council of the Society.

The President announced that no Fellowship nominations for 1941 had been received before the due date of May 1, 1941, and that no election would be held this year.

F. Walker was admitted to Fellowship of the Society.

Communications:—

"Fossil Flora of the Witteberg Series," by J. V. L. Rennie and E. D. Mountain.

"The Comparative Anatomy of the Promontory Region and of the Bony Cochlea in Mammals," by J. A. Keen.

Discussion.—"Hydroponics: the Growing of Plants in Chemical Solutions without Soil," by Miss E. L. Stephens.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, June 18, 1941, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of May 21, 1941, were passed.

The President announced the appointment of E. L. GILL and H. E. WOOD as Vice-Presidents for 1941.

Communications:—

"South African Stone Axe-heads and their Evolution," by H. S. HARGER.

"On the Relations between the Incidence of Rain and the Distribution of Rainfall," by H. G. FOURCADE.

"A Consideration of the Successional Theory of Teeth," by F. G. CAWSTON.

The paper deals with an accumulation of evidence, intended to disprove the successional theory of tooth-replacement, from observations conducted in Natal on the dentition of sharks, rays, fishes, lizards, and snakes.

"Metamorphosed Sediments from the Goodhouse-Pella Area, Namaqualand, South Africa," by C. B. COETZEE (communicated by F. WALKER).

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, August 20, 1941, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of June 18, 1941, were passed.

FREDERICK CLIFFORD TOMPKINS was nominated to Membership of the Society; proposed by S. F. BUSH, seconded by L. C. KING.

The President announced that he had been re-elected an Honorary Member of the Chemical, Metallurgical, and Mining Society of South Africa.

Communications:—

"Mean Yearly Value of the Earth's Magnetic Field at the Magnetic Observatory, Cape Town (Lat. 33° 57′ S., Long. 18° 28′ E.)," by A. OGG.

"New South African Mites of the Genus *Tenuipalpus* Donnedieu (Tetranychidae)," by R. F. LAWRENCE.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, September 17, 1941, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of August 20, 1941, were read and passed.

FREDERICK CLIFFORD TOMPKINS was elected to Membership of the Society.

MERVYN DAVID WALDEGRAVE JEFFREYS was nominated to Membership of the Society; proposed by I. SCHAPERA, seconded by A. J. H. GOODWIN.

Communications:—

"Estimation of the Equivalent Weight of an Organic Base by the Titration of its Picrate," by M. L. SAPIRO (communicated by M. RINDL).

Consists of a description of the chemical and electrometrical methods employed, with curves indicating the results of various estimations.

"The Genus *Austrosparus* Smith," by J. L. B. SMITH.

"Magnetic Observations at the Secular Variation Field Stations in the Union of South Africa and South West Africa, and a Comparison with Corresponding Values at the Magnetic Observatory, Cape Town," by A. OGG.

DEMONSTRATION.—"A Simple Form of Slit Ultramicroscope," by E. NEWBERY.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, October 15, 1941, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of September 17, 1941, were passed.

As no nominations for Fellowships had been received, no Anniversary Meeting is being held.

MERVYN DAVID WALDEGRAVE JEFFREYS was elected to Membership.

PETRUS BASSON ACKERMANN, proposed by F. WALKER, seconded by A. R. E. WALKER, was nominated to Membership of the Society.

Communications:—

"The Metasomatism of Karroo Sediments by Dolerite," by F. WALKER and A. POLDERVAART.

"A Note on the Causal Interpretation of the Forms of Foraminiferan Tests," by H. SANDON.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, November 19, 1941, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of October 15 were passed.

The President referred to the death of E. E. GALPIN, a Member of the South African Philosophical and Royal Societies since 1904. A motion of sympathy was passed.

P. B. ACKERMANN was elected to Membership of the Society.

The President announced the following Nominations for Election to Council for 1941:—President, A. BROWN; Treasurer, R. W. JAMES; Secretary, A. J. H. GOODWIN; Editor, *A. L. DU TOIT; Librarian, E. NEWBERY. Other Members of Council:—G. ARNOLD, W. F. BARKER, E. GILL, *S. H. HAUGHTON, J. JACKSON, *R. F. LAWRENCE, *S. M. NAUDE, *H. R. RAIKES, C. VON BONDE.

Retiring Members:—L. CRAWFORD, Mrs. LEVYNS, M. RINDL, L. VERWOERD, and H. E. WOOD.

The President presented the Senior Captain Scott Medal to Mrs. BOLUS, on behalf of the Biological Society of South Africa. Miss STEPHENS accepted the medal in the absence of Mrs. BOLUS.

Communications:—

"Diurnal Variations of the Earth's Magnetic Field at the Magnetic Observatory, Cape Town, during the years 1933–1940," by B. GOTSMAN (communicated by A. OGG).

"A Contribution to our Knowledge of the South African Restionaceae," by N. S. PILLANS (communicated by Mrs. BOLUS).

"The Kinetics of the Oxidation of Organic Compounds by Potassium Permanganate: Part IV," by F. C. TOMPKINS and L. M. HILL.

* Additional Members.

Lecture.—"The Use of the Digging-stick Stone among Bantu Tribes of the Transvaal and Southern Rhodesia," by A. J. H. Goodwin.

A. J. H. Goodwin,
Hon. General Secretary.

Anniversary Meeting.

The Anniversary Meeting of the Society was held on Wednesday, March 18, 1942, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. Crawford, was in the Chair.

Business:—

The Annual Report of the Hon. General Secretary for 1941 was read and passed.

The Annual Report of the Hon. Treasurer for 1941 was read and passed.

The following were elected as Officers and Members of the Council for 1942:—President, A. Brown; Hon. Treasurer, R. W. James; Hon. General Secretary, A. J. H. Goodwin; Hon. Editor of Transactions, A. L. du Toit; Hon. Librarian, E. Newbery. Other Members of Council:—G. Arnold, W. F. Barker, E. L. Gill, S. H. Haughton, J. Jackson, R. F. Lawrence, S. M. Naudé, H. R. Raikes, C. von Bonde.

Ordinary Meeting.

The Anniversary Meeting was followed by an Ordinary Meeting.

The Chair was taken by the President, Professor A. Brown.

Professor Brown proposed, as an unopposed motion, that the Society record its appreciation of the exceptional services rendered to the Society by the outgoing President, both in the offices held by him, and in the earlier history of the Society.

Business:—

The Minutes of the Ordinary Meeting of November 19, 1941, were passed.

Communications:—

"The Origin of the Tetrapods," by H. Leighton Kesteven (communicated by J. L. B. Smith).

"Interesting Early Juvenile Stadia of certain well-known South African Fishes," by J. L. B. Smith.

"Evaporation of Rainwater from Standard Rain Gauges," by C. L. Wicht, Forest Research Officer, Jonkershoek.

The following three treatments of standard rain-gauges of the Snowdon type, were tested in an experiment in which each treatment was replicated four times in randomised blocks: (*a*) daily readings at 8.30 a.m.; (*b*) monthly readings; (*c*) monthly readings with addition of 50 c.c. of liquid paraffin.

It was found that evaporation losses from monthly read gauges in summer caused these to give highly significant lower readings than daily gauges. In winter losses were negligible. For the whole year 3·86 inches or 5·64 per cent. were lost from a rainfall of 68·39 inches recorded by daily gauges. Addition of liquid paraffin to monthly gauges effectively prevented such losses and gave readings agreeing closely with the mean of daily read gauges.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, April 15, 1942, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of March 18, 1942, were passed, the name of the outgoing President, Dr. L. Crawford, having been added to the unopposed motion.

Communication:—

"The Energy and Entropy of Activation of the Reaction between the Permanganate and the Formate Ion," by L. M. Hill and F. C. Tompkins.

Discussion.—"Rubber," introduced by P. C. Carman and A. M. Stephen.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, May 20, 1942, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of April 15, 1942, were passed.

H. T. Gonin was nominated to Membership of the Society; proposed by L. Crawford, seconded by A. Brown.

Communication:—

"Interesting New Fishes of three Genera new to South Africa, with a note on *Mobula diabolus*, Shaw," by J. L. B. Smith.

Discussion.—"Madagascar and its Peoples," introduced by A. L. du Toit, W. Talbot, R. S. Adamson, A. J. H. Goodwin, and G. P. Lestrade.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, June 17, 1942, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of May 20, 1942, were passed.

The President announced his nomination of J. Jackson and R. A. Dart as Vice-Presidents of the Society for 1942.

W. W. E. Giles was nominated to Membership; proposed by J. Smeath Thomas, seconded by J. Omer-Cooper.

H. T. Gonin was elected to Membership of the Society.

Communications:—

"The Origin of the Kentani 'Gap-dykes,'" by Frederick Walker.

"Time and Mass as Oecological Factors. Part I," by J. Omer-Cooper.

Discussion.—"Dietetics," introduced by L. Mirvish. Rees Davies and others continued the discussion.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, August 19, 1942, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of June 17, 1942, were read and passed.

W. W. E. Giles was elected to Membership of the Society.

It was reported that the names of three Members had been submitted to Council, and had been accepted as nominations for election to Fellowship. Permission was given to notify these names to the Society at the next

meeting. The election will take place at the Annual Meeting to be held on Wednesday, October 14, 1942.

Communications:—

"Report on the Excavations at Hyrax Hill, Nakuru, Kenya Colony," by M. D. Leakey.

"Suicide," by M. D. W. Jeffreys.

"The Vitamin D Content of certain South African Foods and Preparations," by H. A. Shapiro.

The values shown in the table below have been determined by the "line" test on Rats:—

Gluten flour	No biological activity.
Vegetable Oils:	
Olive oil	No biological activity.
Arachis (peanut) oil	No biological activity.
Fish-liver oils:	
Trachurus trachurus (Maasbanker)	No biological activity in 0·02 c.c.
Galeorhinus canis (Soupfin shark)	Traces of activity in 0·01 c.c.
Merluccius capensis (Stockfish)	230 I.U. per gm.
Thyrsites atun (Snoek)	1300 I.U. per gm.
Johnius hololepidotus	2666 I.U. per gm.
Sarda sarda (bonito, tuna)	40,000 I.U. per gm.
Raw bird liver	2 I.U. per gm.
A first grade South African butter	1 I.U. per gm.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, September 16, 1942, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of August 19, 1942, were passed.

The President announced the following nominations for Election to Fellowship for 1942:—Isaac Donen, M.Sc., Ph.D., proposed by R. S. Adamson, W. Pugh, J. Smeath Thomas, and M. R. Levyns; Douglas Leinster Scholtz, D.Sc., proposed by F. Walker, A. W. Rogers, R. S. Adamson, and M. R. Levyns; Christiaan Lodewyk Wicht, B.A., B.Sc., D.Ing., proposed by R. H. Compton, E. L. Stephens, M. R. Levyns, and R. S. Adamson.

Stanley Percival Jackson was nominated to Membership of the Society; proposed by J. Jackson, seconded by A. Brown.

Discussion.—"Wartime Substitutes," by E. R. Roux, F. Walker, S. Garside, and W. E. Isaac.

A. J. H. Goodwin,
Hon. General Secretary.

Annual Meeting.

The Annual Meeting of the Society was held on Wednesday, October 14, 1942, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The following were duly elected to Fellowship of the Society:—Isaac Donen, Douglas Leinster Scholtz, and Christiaan Lodewyk Wicht.

Ordinary Meeting.

The Annual Meeting was followed by an Ordinary Meeting.

Business:—

The Minutes of the Ordinary Meeting of September 16, 1942, were passed.

The President drew the attention of the Society to the deaths of T. N. Leslie, of Vereeniging, and W. Coulson Tregarthen, of Queenstown, both members of the Society.

S. P. Jackson was elected to Membership of the Society.

Communication:—

"Artificial Interference with Molluscan Life in Rivers," by F. Gordon Cawston.

Disappearance of molluscan life from South African rivers during the last twenty years may be traced to the extensive removal of natural bush with its variety of plant-life surrounding streams, and its replacement by one kind of plant without the essential undergrowth to control soil erosion and the washing away of valuable surface soil during heavy rains.

Anti-mosquito measures have destroyed many molluscan species without much influence on the heavier *Physopsis africana* Krauss, which continues to breed in pools where its natural enemies, including fish, have succumbed to the oiling or partial drainage of unnecessary collections of water. They have also resulted in a lessening of the plant-life on which animal surface life depends.

Even where anti-mosquito measures are not of importance the banks of rivers have been robbed of their shade by extensive grass-firing, a greater menace to animal life along the course of rivers and in vleis than even over-stocking with goats. This practice influences both bird and fish life unfavourably.

DISCUSSION.—"Brown Bread," by A. A. MEYER, H. A. SHAPIRO, W. H. SEATH, and L. MIRVISH. H. B. S. COOKE and others joined in the subsequent debate.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, November 18, 1942, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. BROWN, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of October 14, 1942, were passed.

E. L. WICHT was admitted to Fellowship of the Society.

H. H. DODDS was nominated for election to Membership of the Society; proposed by F. GORDON CAWSTON, seconded by A. J. H. GOODWIN.

The President drew the attention of the Society to the death of THOMAS STEWART, M.I.C.E., F.G.S. Born in Perthshire in 1857, Mr. Stewart came to South Africa in 1882, and joined the South African Philosophical Society in the following year. He was elected President, and held that position from July 1892 to June 1894. On the creation of the Royal Society of South Africa he transferred, and remained a Member of this Society until his death in October at the age of eighty-five years.

Mr. Stewart was engineer to the Table Mountain Reservoirs, the Steenbras waterworks, the Zuurbekom waterworks, and also to waterworks at Worcester, Oudtshoorn, Mossel Bay, and elsewhere. He was a member of various commissions, notably the Geological Commission of the Cape of Good Hope. He was chairman of the S.P.C.A. from 1924 to 1927. He was a keen meteorologist and geologist.

Honorary Fellowship:—

The Rev. the Abbé HENRI EDOUARD PROSPER BREUIL was nominated for election to Honorary Fellowship of the Society; proposed by A. BROWN, E. NEWBERY, A. L. DU TOIT, A. J. H. GOODWIN, and E. L. GILL.

Communications:—

"A Consideration of the Spine in Ova of Schistosoma," by F. GORDON CAWSTON.

Consideration of the size of the spines on the shells of Schistosome ova compared with the rest of the shell, and of the tissues through which they pass, shows that they can have little influence in penetrating the vein-wall of the final host.

Some species with small spines have no greater difficulty in escaping from the venous circulation than those possessing ova with larger ones. Even long spindle-shaped ova do not cause more haemorrhage than commonly occurs when ova of a schistosome laying oval ova is harboured. There is, however, a relation between the environment of the escaping *miracidia* of a species of schistosome and the size of the spine of its shell, spindle-shaped ova with terminal spine and ova with a stout lateral spine being less likely to be blown away by the wind.

Thus schistosome ova which need to be hatched near the molluscs of marshy environment are elongated, or have a hook-like spine to the shell, whilst those whose larvae need to reach a river-snail in order to complete the life-cycle are oval or nearly round, and have small spines to the shell.

"The Determination of the Horizontal Component of the Earth's Magnetic Force at the Magnetic Observatory, Hermanus," by A. Ogg, B. Gotsman, and A. M. van Wijk.

"The Petrology of the Elephant's Head Dyke and New Amalfi Sheet, Transkei," by A. Poldervaart (communicated by F. Walker).

Discussion.—"Some Aspects of the Tsetse Fly and Cattle Nagana," by L. Gill, A. J. H. Goodwin, and S. H. Skaife.

Following the discussion, Dr. Skaife proposed that Council consider the advisability of asking the Government to study all scientific methods of Tsetse and Nagana control employed in Natal and elsewhere in Africa before resorting to the expedient of game destruction in reserves.

A. J. H. Goodwin,
Hon. General Secretary.

Bd. Per. Ser.